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Yost et al.

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(54) **VEHICLE-DETECTING UNIT FOR USE WITH ELECTRONIC PARKING METER**

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(73) Assignee: **Intelligent Devices, Inc.**, Harleysville, PA (US)

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(22) Filed: **Mar. 17, 1999**

Related U.S. Application Data

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(51) **Int. Cl.**[7] **G08G 1/04**

(52) **U.S. Cl.** **340/943**; 340/932.2; 340/933

(58) **Field of Search** 340/942, 943, 340/933, 932.2, 935–937

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Primary Examiner—Daniel J. Wu
Assistant Examiner—Sihong Huang
(74) *Attorney, Agent, or Firm*—Caesar, Rivise, Bernstein, Cohen & Pokotilow, Ltd.

(57) **ABSTRACT**

A vehicle detector unit and detection method for use with an electronic parking meter for providing the electronic parking meter with the ability to reliably detect the presence or absence of a vehicle in any existing corresponding parking space, independent of the surrounding environment, while using a minimum of power.

53 Claims, 13 Drawing Sheets

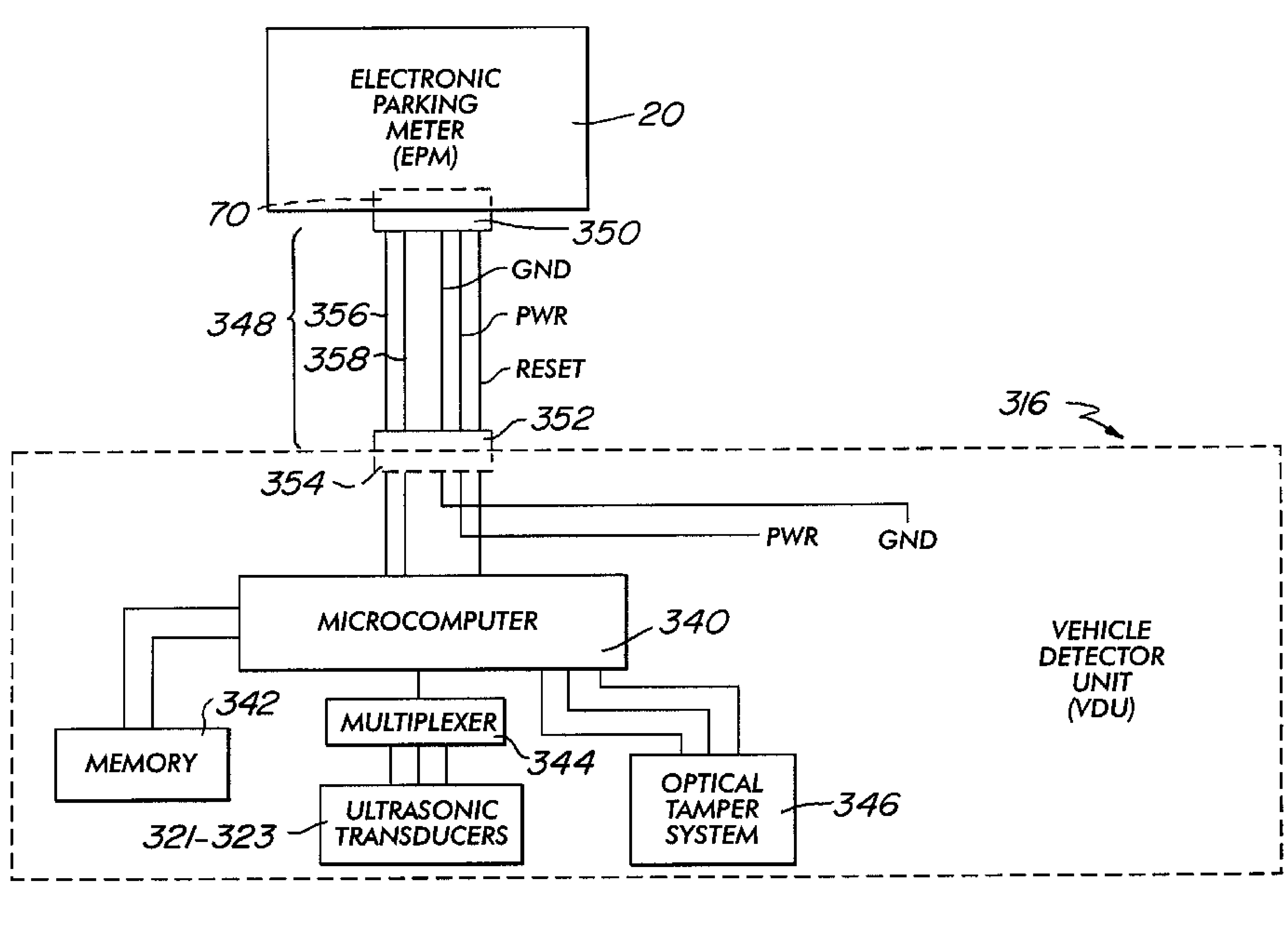


FIG. 1

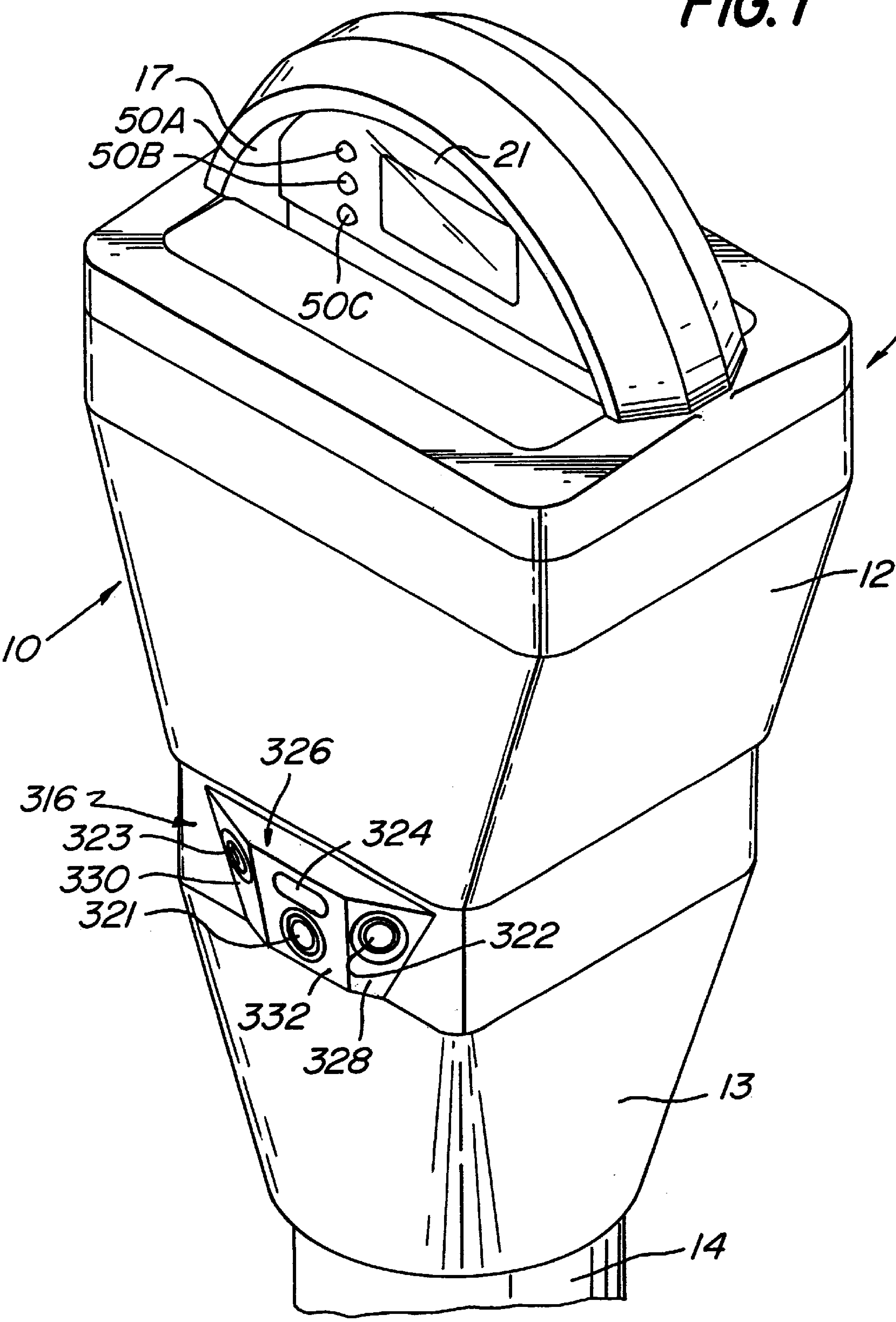

17
50A
50B
21
50C
15
12
10
326
316
323
324
330
321
322
332
328
13
14

FIG. 1A

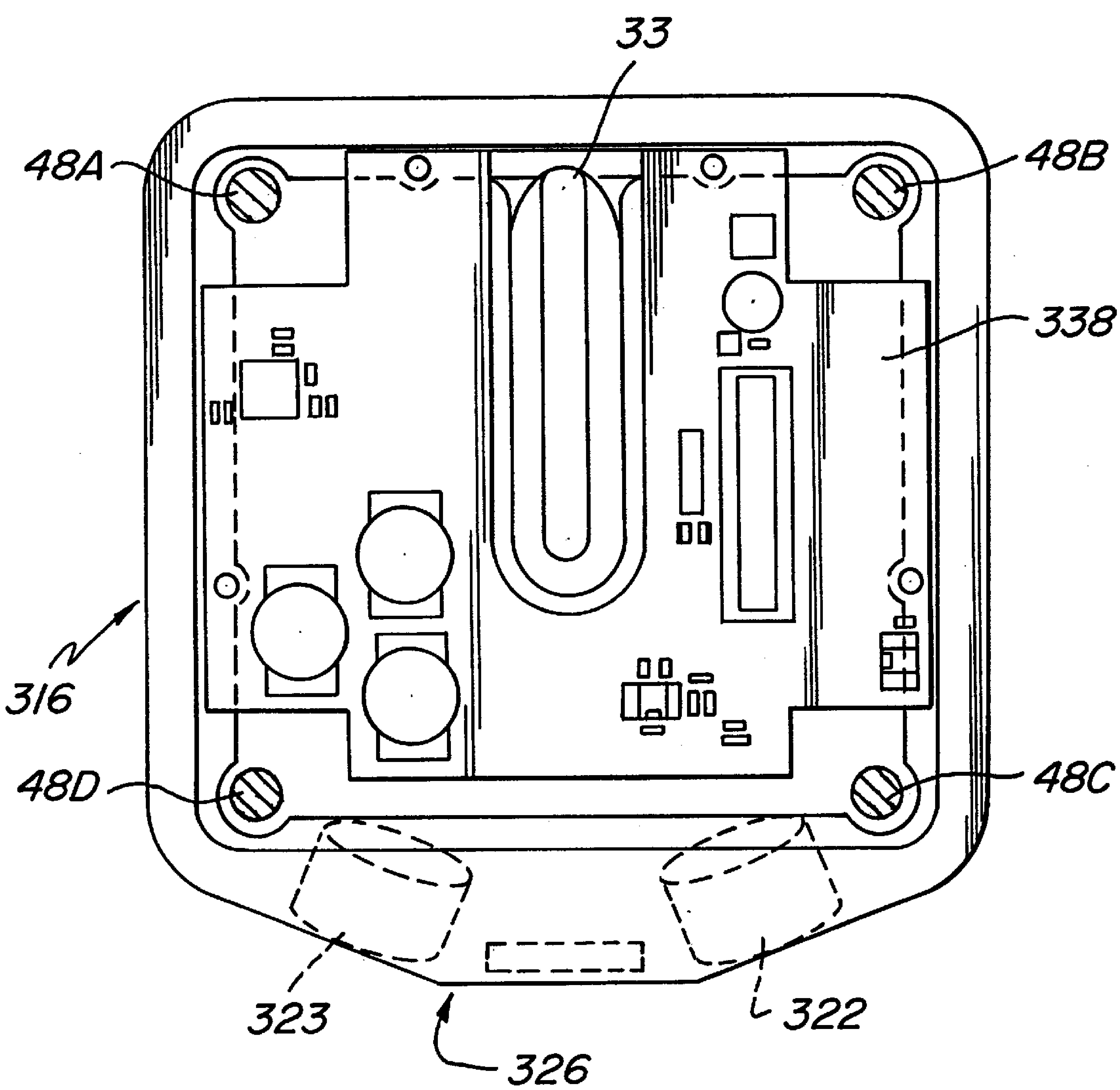


FIG. 2

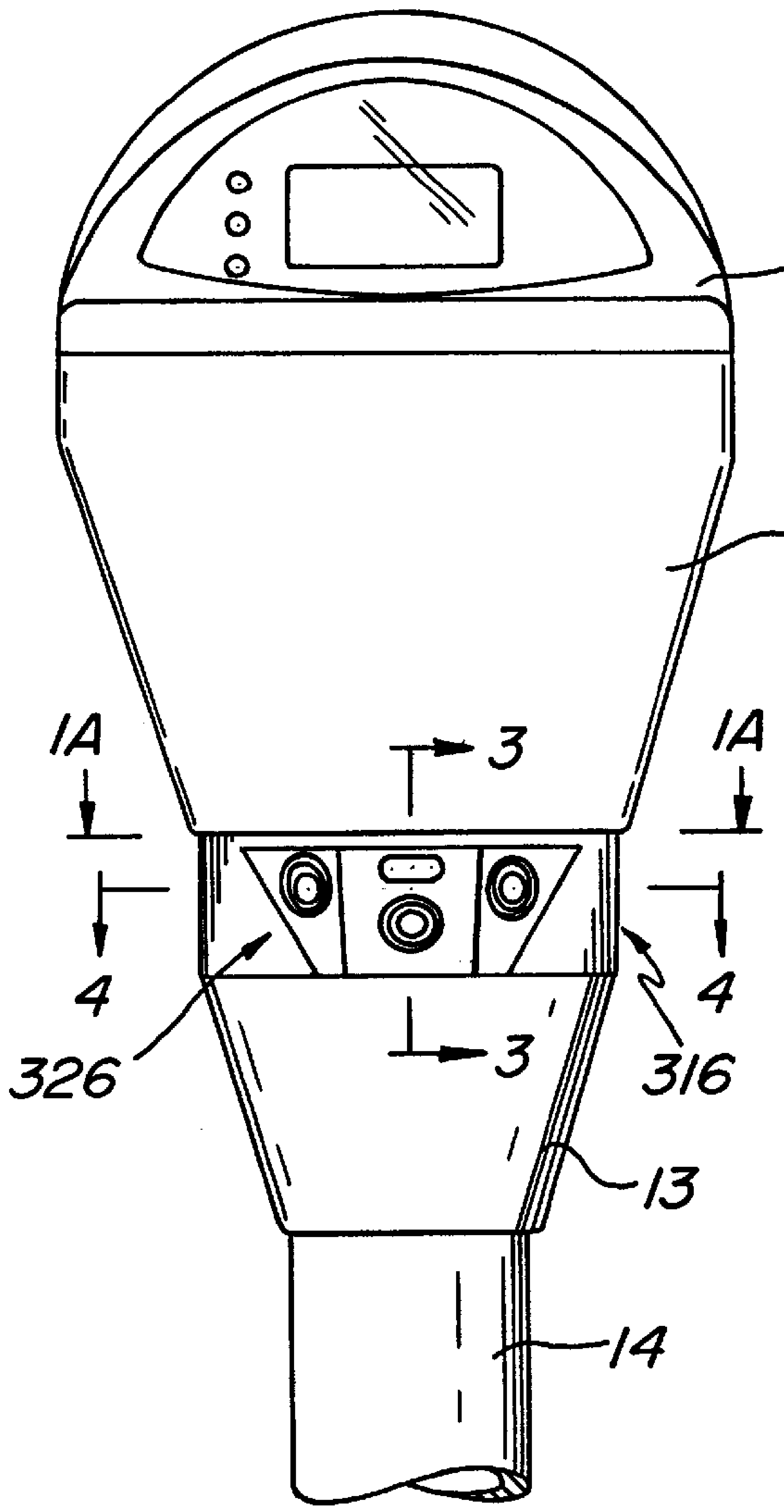


FIG. 3

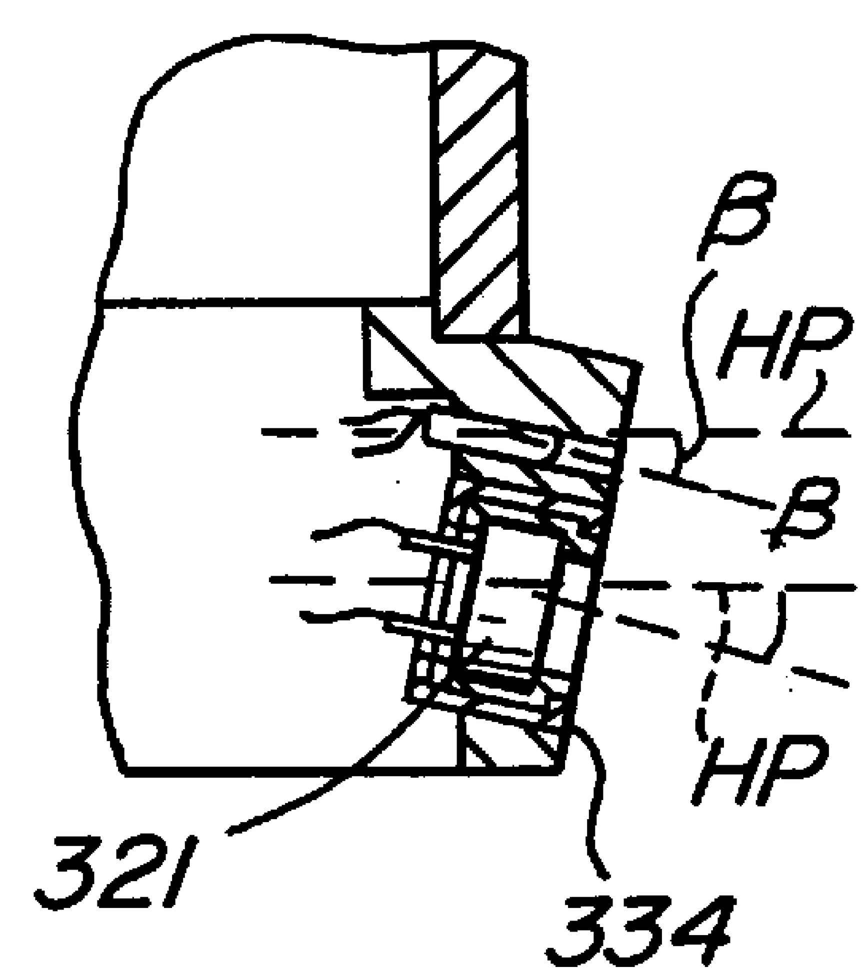
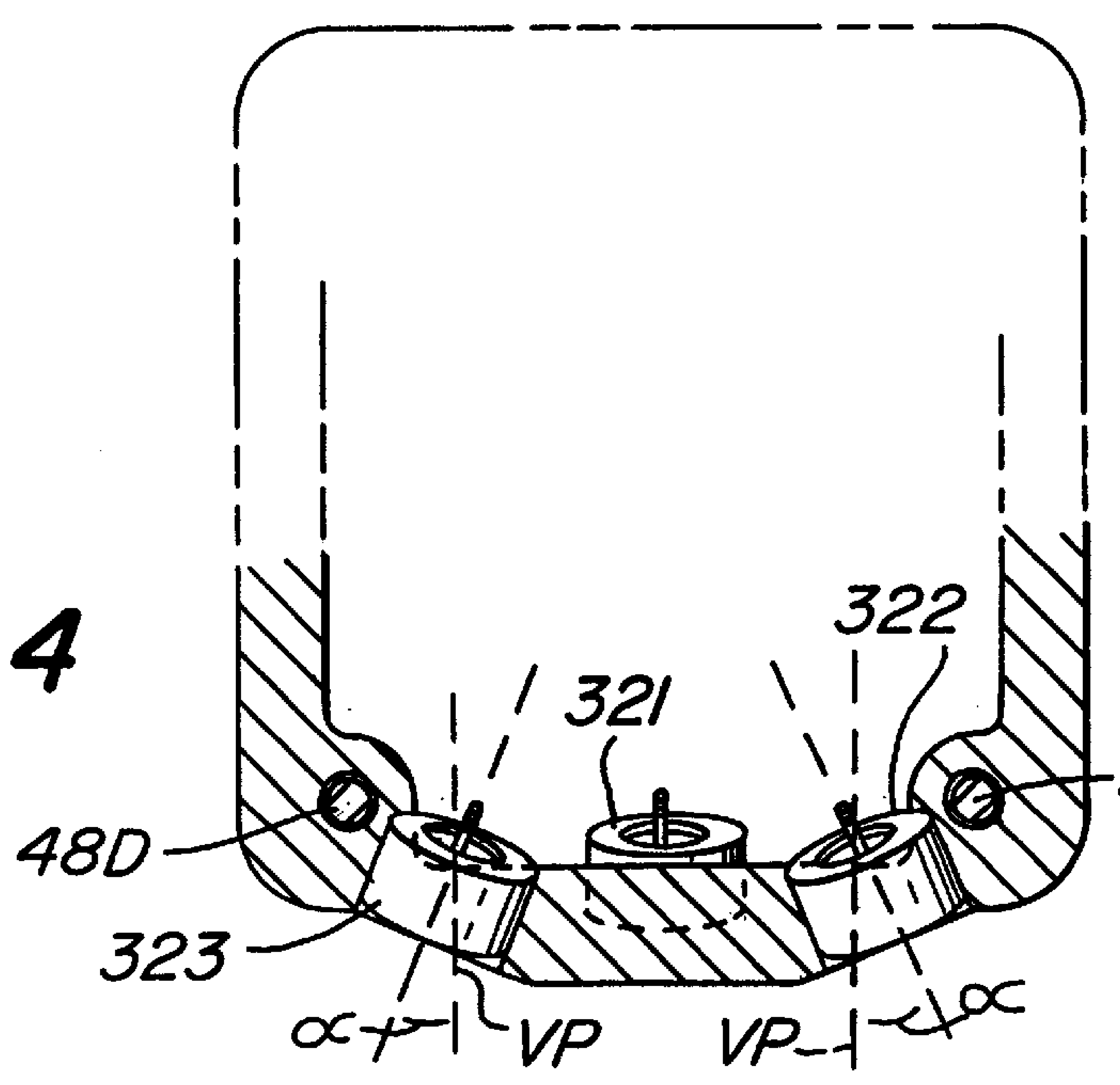


FIG. 4



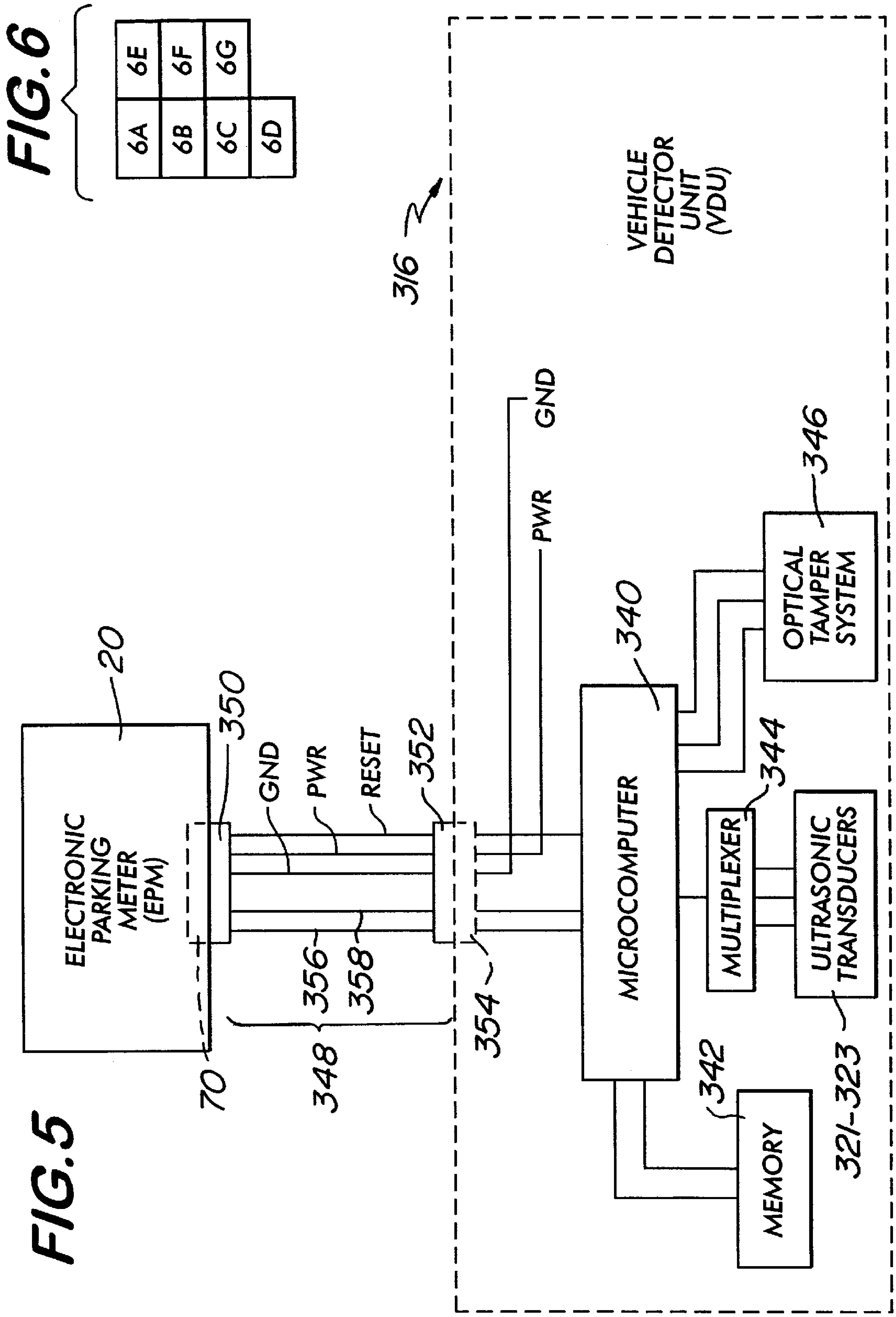


FIG.6
6A
6B
6C
6D
6E
6F
6G
316
VEHICLE DETECTOR UNIT (VDU)
GND
PWR
346
OPTICAL TAMPER SYSTEM
340
MICROCOMPUTER
344
MULTIPLEXER
ULTRASONIC TRANSDUCERS
321-323
342
MEMORY
20
ELECTRONIC PARKING METER (EPM)
350
GND
PWR
RESET
352
356
358
354
348
70
FIG.5

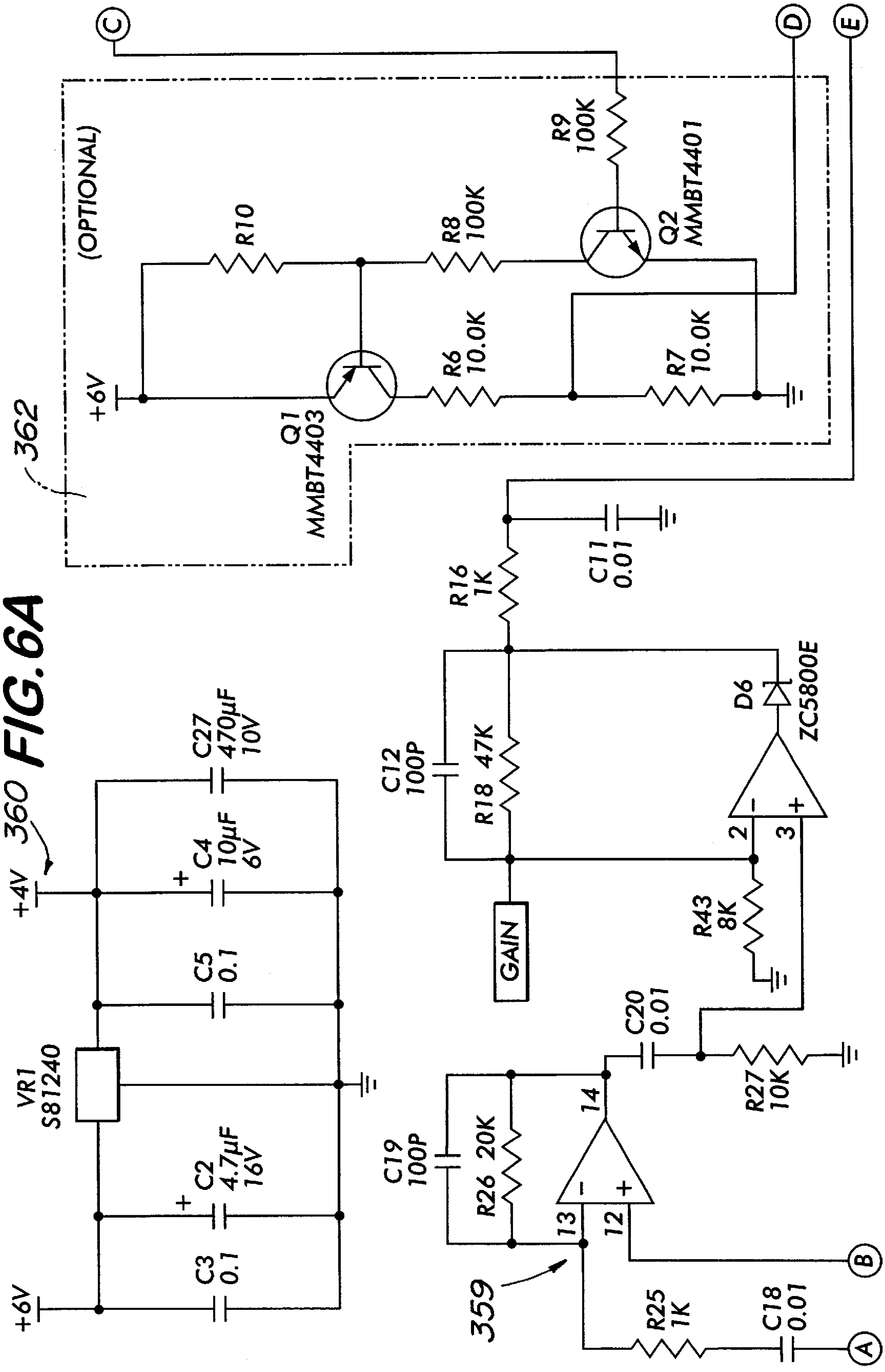

C
D
E
(OPTIONAL)
R10
R8
100K
R9
100K
Q2
MMBT4401
+6V
R6
10.0K
R7
10.0K
Q1
MMBT4403
362
C11
0.01
R16
1K
D6
ZC5800E
C12
100P
R18 47K
2
3
R43
8K
GAIN
C20
0.01
R27
10K
14
C19
100P
R26 20K
13
12
B
359
R25
1K
C18
0.01
A
360
+4V
C27
470µF
10V
C4
10µF
6V
C5
0.1
VR1
S81240
C2
4.7µF
16V
C3
0.1
+6V

FIG.6A

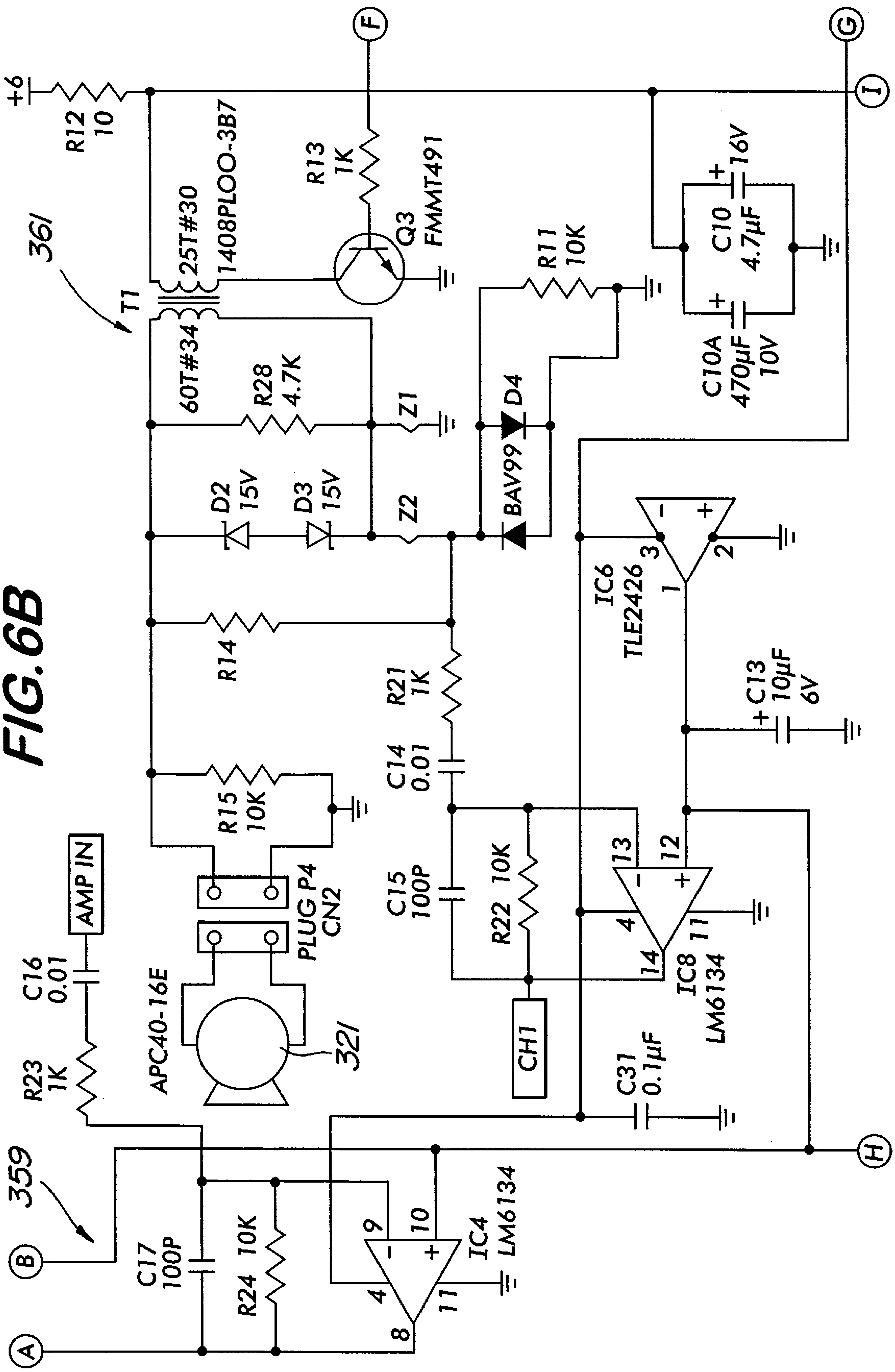

+6
R12 10
361
T1
25T#30
1408PLOO-3B7
60T#34
R13 1K
Q3 FMMT491
R28 4.7K
Z1
D2 15V
D3 15V
Z2
R11 10K
D4
BAV99
C10 4.7μF 16V
C10A 470μF 10V
R14
R21 1K
C14 0.01
R15 10K
PLUG P4 CN2
AMP IN
C16 0.01
R23 1K
APC40-16E
321
C15 100P
R22 10K
CH1
IC6 TLE2426
C13 10μF 6V
IC8 LM6134
C31 0.1μF
359
C17 100P
R24 10K
IC4 LM6134

FIG. 6B

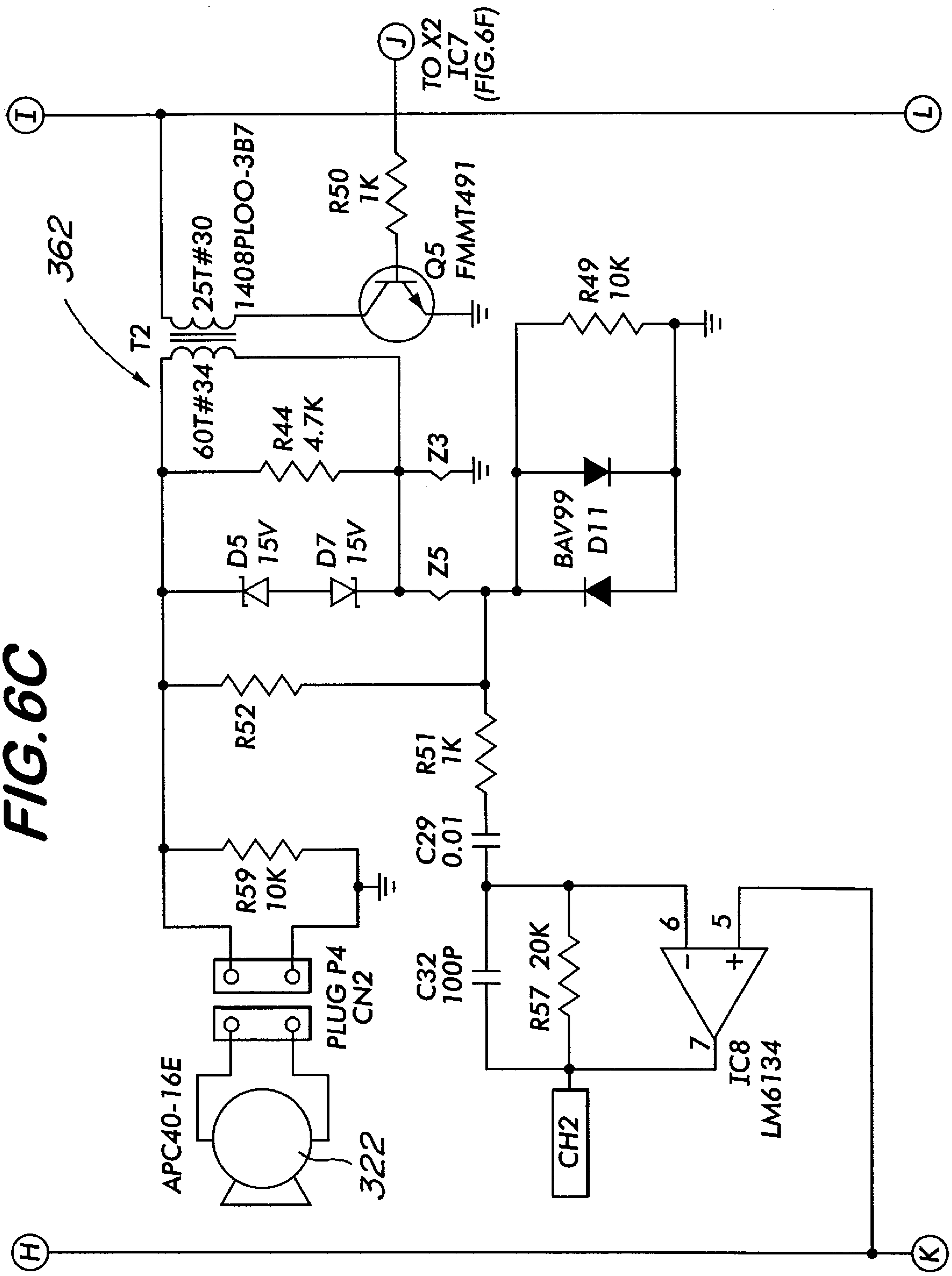

I
L
J
TO X2
IC7
(FIG.6F)
H
K
362
T2
25T#30
1408PLOO-3B7
60T#34
R50
1K
Q5
FMMT491
R49
10K
R44
4.7K
Z3
D5
15V
D7
15V
Z5
BAV99
D11
R52
R51
1K
C29
0.01
R59
10K
C32
100P
R57 20K
6
5
7
IC8
LM6134
PLUG P4
CN2
APC40-16E
322
CH2

FIG. 6C

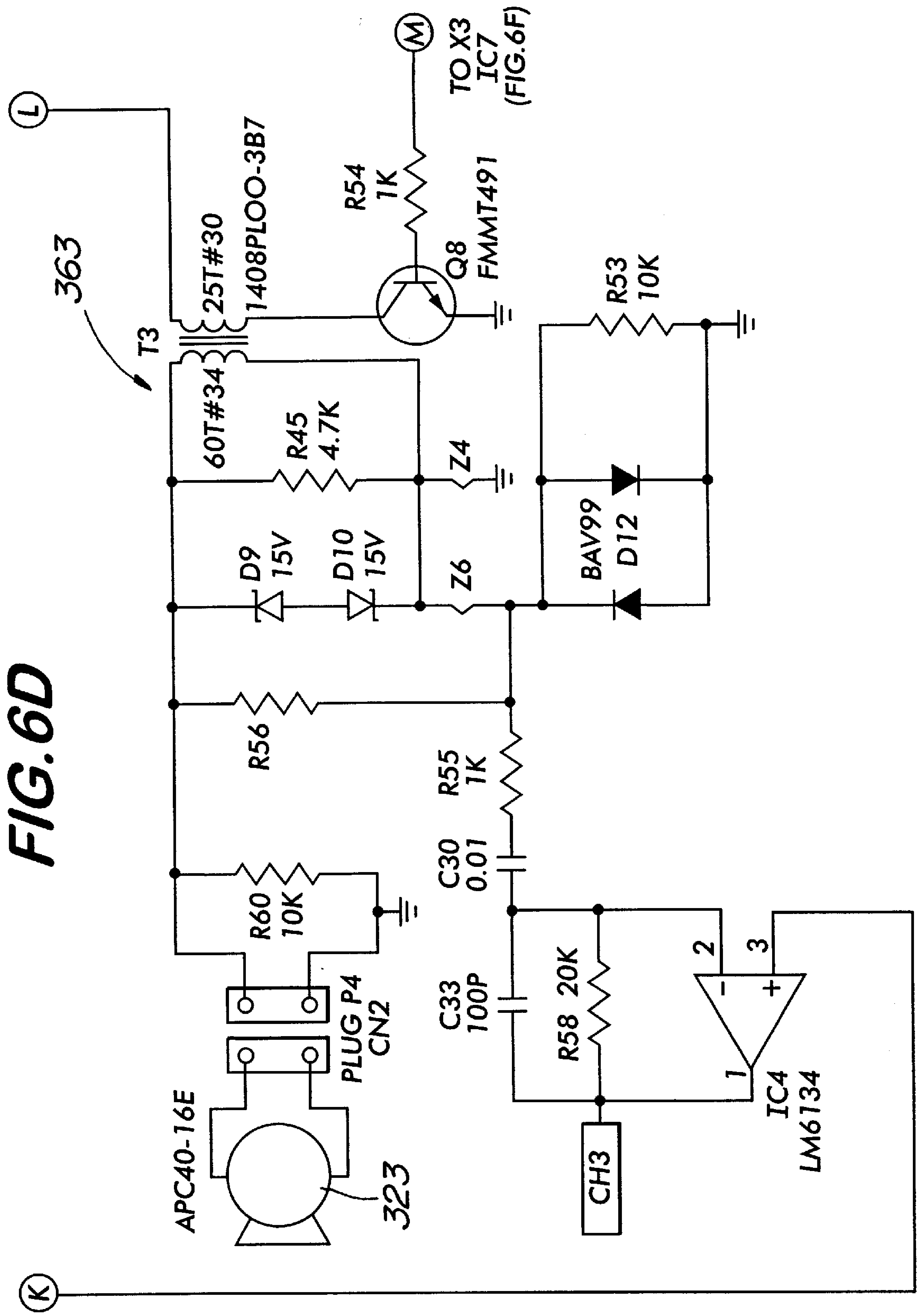
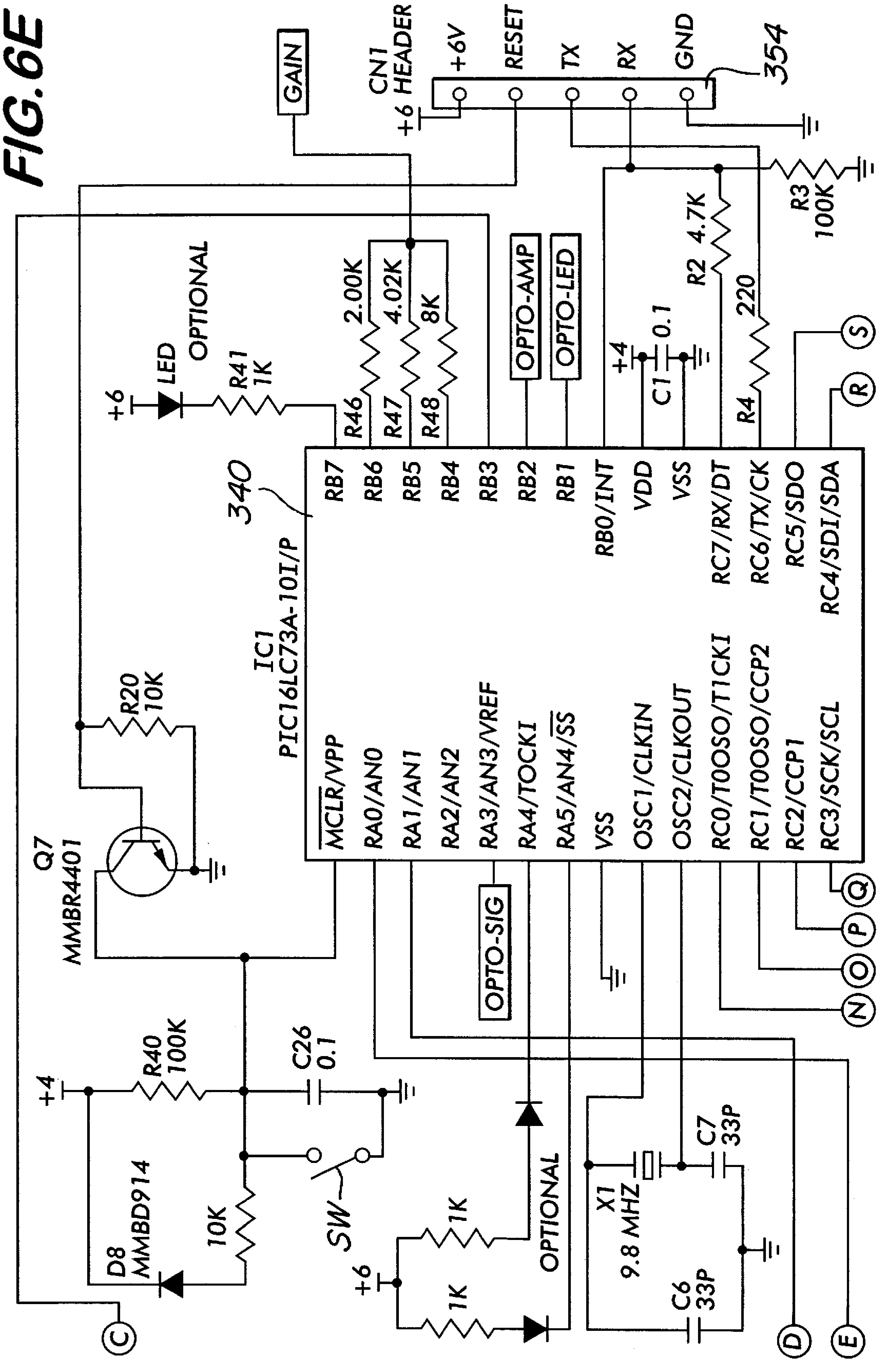
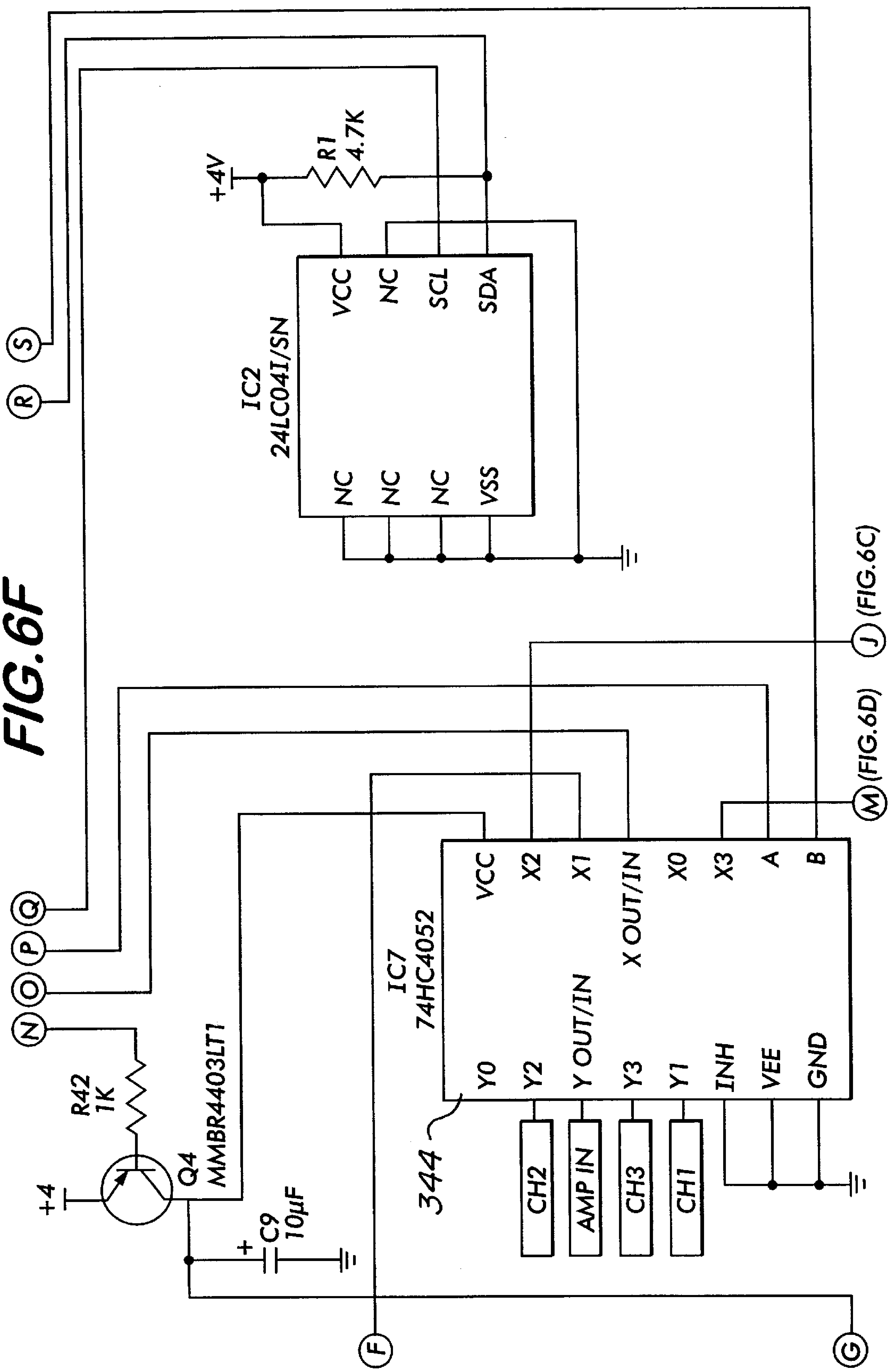

L
M
TO X3
IC7
(FIG.6F)
363
T3
25T#30
1408PLOO-3B7
60T#34
R54
1K
Q8
FMMT491
R53
10K
R45
4.7K
Z4
D9
15V
D10
15V
Z6
BAV99
D12
R56
R55
1K
C30
0.01
R60
10K
C33
100P
R58 20K
2
3
1
IC4
LM6134
PLUG P4
CN2
APC40-16E
323
CH3
K

FIG.6D

FIG. 6E


GAIN
CN1
+6 HEADER
+6V
RESET
TX
RX
GND
354
R3
100K
R2 4.7K
220
R4
C1 0.1
+4
OPTO-AMP
OPTO-LED
2.00K
4.02K
8K
R46
R47
R48
LED
OPTIONAL
R41
1K
+6
340
IC1
PIC16LC73A-10I/P
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0/INT
VDD
VSS
RC7/RX/DT
RC6/TX/CK
RC5/SDO
RC4/SDI/SDA
MCLR/VPP
RA0/AN0
RA1/AN1
RA2/AN2
RA3/AN3/VREF
RA4/TOCKI
RA5/AN4/SS
VSS
OSC1/CLKIN
OSC2/CLKOUT
RC0/T0OSO/T1CKI
RC1/T0OSO/CCP2
RC2/CCP1
RC3/SCK/SCL
S
R
Q
P
O
N
Q7
MMBR4401
R20
10K
OPTO-SIG
R40
100K
C26
0.1
D8
MMBD914
10K
SW
1K
1K
OPTIONAL
X1
9.8 MHZ
C7
33P
C6
33P
C
D
E



S
R
+4V
R1
4.7K
IC2
24LC04I/SN
VCC
NC
SCL
SDA
NC
NC
NC
VSS
J
(FIG.6C)
M
(FIG.6D)
Q
P
O
N
R42
1K
+4
Q4
MMBR4403LT1
IC7
74HC4052
VCC
X2
X1
X OUT/IN
X0
X3
A
B
Y0
Y2
Y OUT/IN
Y3
Y1
INH
VEE
GND
344
CH2
AMP IN
CH3
CH1
+
C9
10μF
F
G

FIG.6F

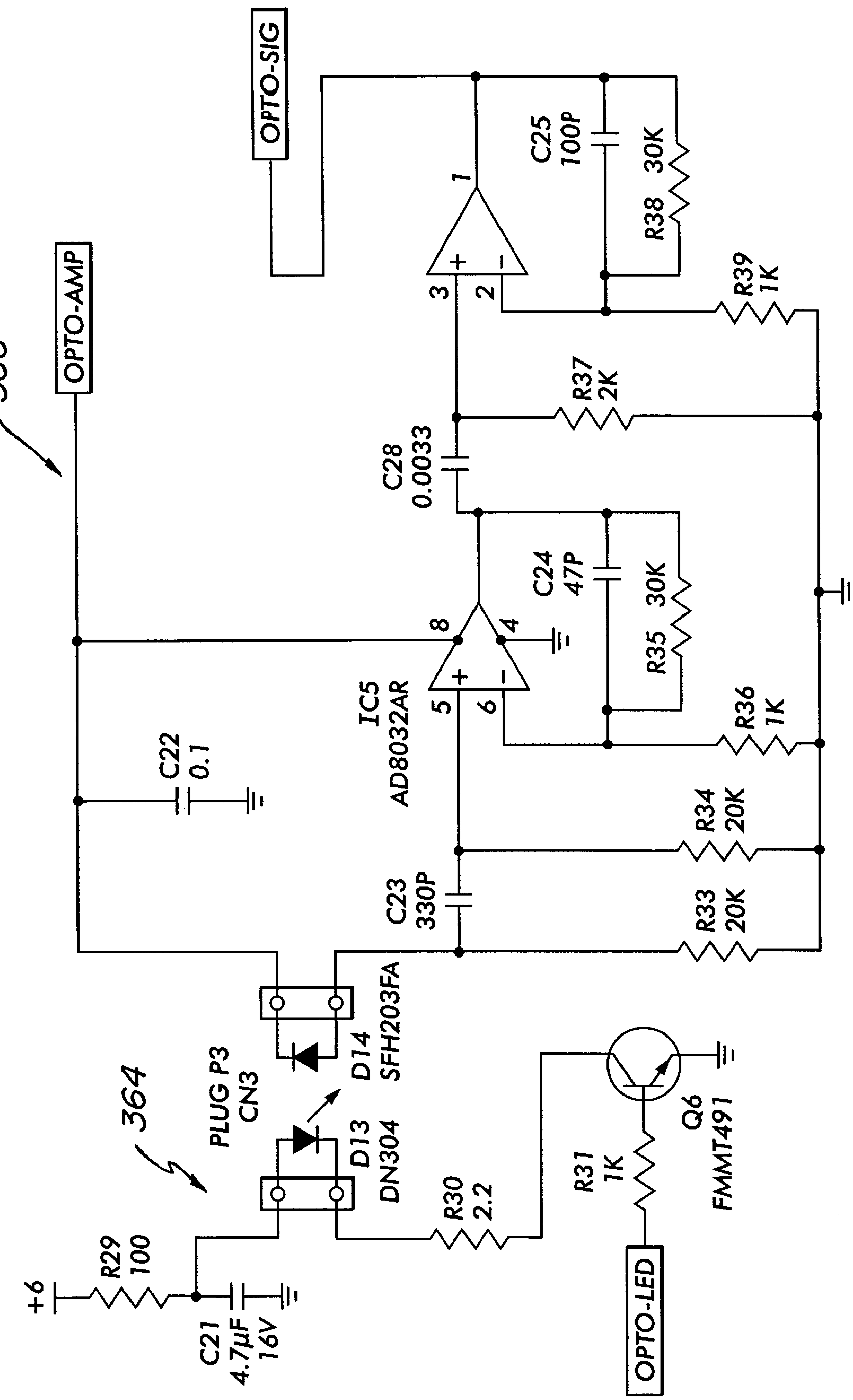

366
364
OPTO-AMP
OPTO-SIG
OPTO-LED
+6
R29 100
C21 4.7μF 16V
PLUG P3 CN3
D13 DN304
D14 SFH203FA
R30 2.2
R31 1K
Q6 FMMT491
C22 0.1
C23 330P
R33 20K
R34 20K
IC5 AD8032AR
R35 30K
C24 47P
R36 1K
C28 0.0033
R37 2K
R38 30K
C25 100P
R39 1K
1
2
3
4
5
6
8

FIG.6G

FIG. 7

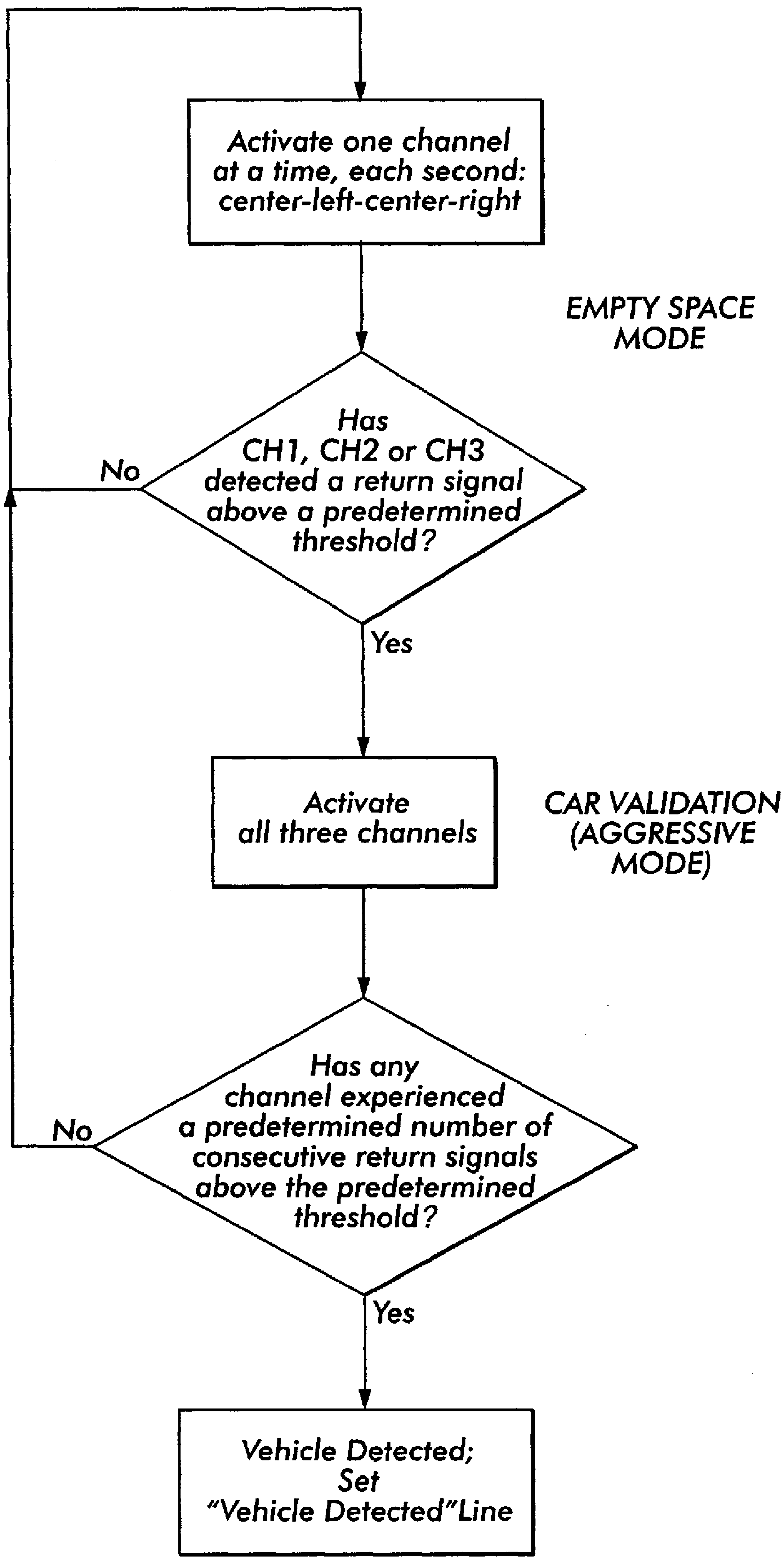
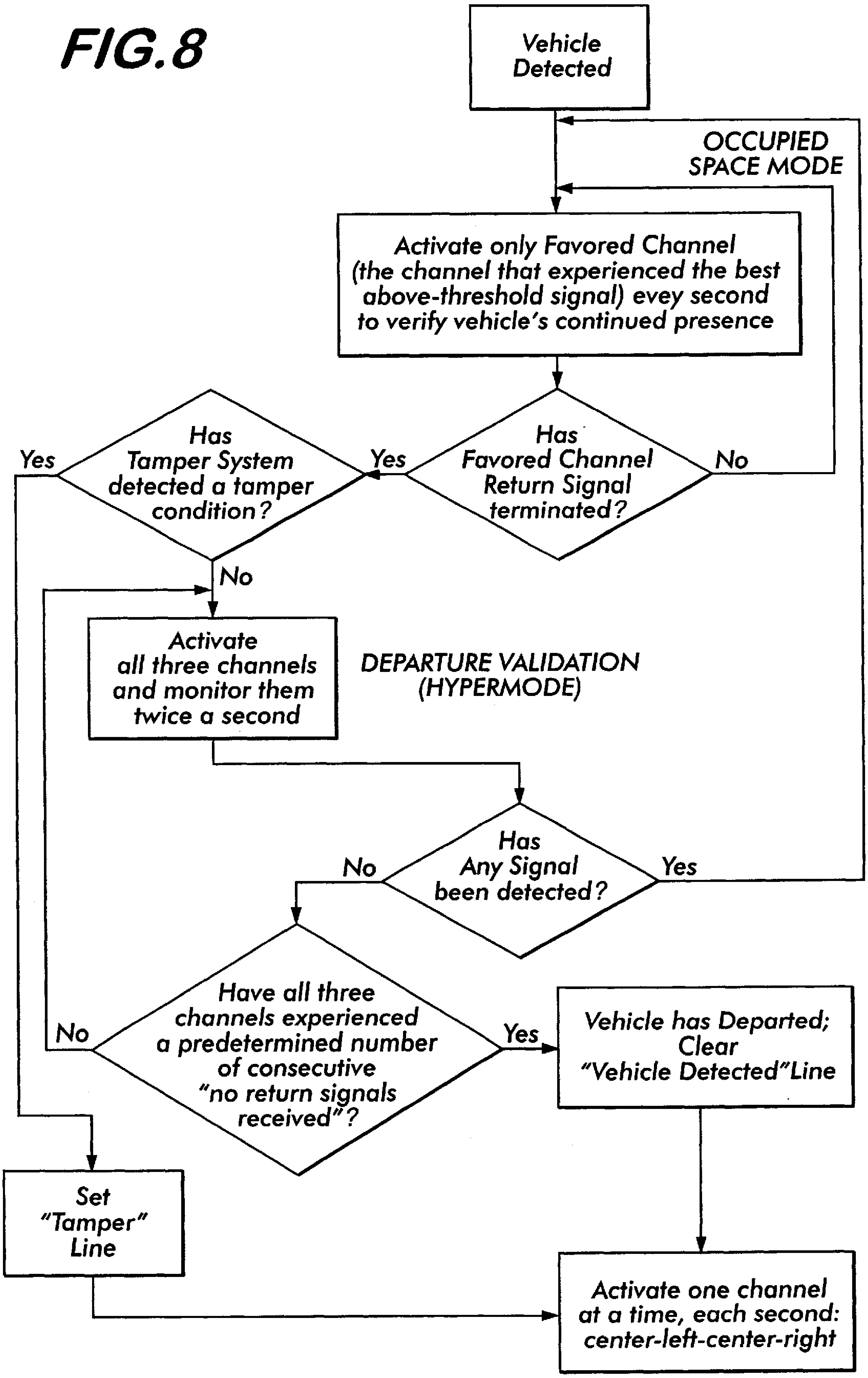

Activate one channel at a time, each second: center-left-center-right
EMPTY SPACE MODE
Has CH1, CH2 or CH3 detected a return signal above a predetermined threshold?
No
Yes
Activate all three channels
CAR VALIDATION (AGGRESSIVE MODE)
Has any channel experienced a predetermined number of consecutive return signals above the predetermined threshold?
No
Yes
Vehicle Detected; Set "Vehicle Detected" Line

FIG. 8


Vehicle Detected
OCCUPIED SPACE MODE
Activate only Favored Channel (the channel that experienced the best above-threshold signal) evey second to verify vehicle's continued presence
Has Favored Channel Return Signal terminated?
No
Yes
Has Tamper System detected a tamper condition?
Yes
No
Activate all three channels and monitor them twice a second
DEPARTURE VALIDATION (HYPERMODE)
Has Any Signal been detected?
Yes
No
Have all three channels experienced a predetermined number of consecutive "no return signals received"?
No
Yes
Vehicle has Departed; Clear "Vehicle Detected" Line
Set "Tamper" Line
Activate one channel at a time, each second: center-left-center-right

VEHICLE-DETECTING UNIT FOR USE WITH ELECTRONIC PARKING METER

RELATED APPLICATIONS

This application is a Continuation-in-Part of Co-Pending application Ser. No. 09/231,718 filed Jan. 15, 1999, entitled TOOL-LESS PARKING METER MECHANISM AND ICON DISPLAY which is assigned to the same Assignee of the present invention, namely Intelligent Devices, Inc. and whose disclosure is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates generally to the field of parking meters and more particularly to electronic parking meters that can detect parked vehicles.

BACKGROUND OF THE INVENTION

Parking meters permit vehicles to be parked on streets for an allowable time determined by the number and denominations of coins which are placed in the parking meter. A clock mechanism in the parking meter runs down the allowable time until it reaches zero, and an overtime parking indication appears.

It has been long recognized that if the parking meter were able to detect the presence or absence of the vehicle, either by mechanical means or wireless means, in the corresponding parking space, then among other things, the parking meter could be reset, thereby requiring the next patron to insert the appropriate amount of payment for his/her parking time. U.S. Pat. No. 3,015,208 (Armer); U.S. Pat. No. 3,018,615 (Minton et al.); U.S. Pat. No. 3,034,287 (Odom et al.); U.S. Pat. No. 3,054,251 (Handley et al.); U.S. Pat. No. 3,064,416 (Armer); U.S. Pat. No. 3,535,870 (Mitchell); U.S. Pat. No. 3,999,372 (Welch); U.S. Pat. No. 4,043,117 (Maresca et al.); U.S. Pat. No. 4,183,205 (Kaiser); U.S. Pat. No. 4,823,928 (Speas); U.S. Pat. No. 4,825,425 (Turner); U.S. Pat. No. 4,908,617 (Fuller); U.S. Pat. No. 4,967,895 (Speas); U.S. Pat. No. 5,442,348 (Mushell); U.S. Pat. No. RE29,511 (Rubenstein).

Thus, the objective of any vehicle detection portion of the electronic parking meter is to, as reliably as possible and as inexpensively as possible, detect when there is and is not a vehicle in the corresponding parking space. In fact, experience has shown that unless vehicle detection is extremely reliable (99%+ in correctly identifying the presence/absence of a vehicle), the customer, i.e., cities and townships, will not invest in vehicle detecting parking meters. However, all of the above references suffer from one of many different problems and actually achieving this objective remains elusive. The reasons for not being able to implement such a working vehicle detector include: the uncertainty of the parking meter location and of the parking meter/space environment, vehicles that are parked too far back in the parking space, the smoothness of the surfaces of different vehicles, the "fast parker", the inadvertent or intentional presence of a person in front of the meter and tampering with the meter including the vandalizing of the sensor itself. Furthermore, the vehicle-detecting parking meter must be able to provide a reliable vehicle-detection scheme that uses low power since the parking meter is a stand-alone device that does not have the luxury of using utility power.

In particular, the environment of the meter/space presents obstacles that must be recognized and compensated for, or distinguished, by the vehicle detector. For example, the road may be very steeply-crowned and an ultrasonic-based vehicle detector will receive reflections from the crowned road, and may erroneously conclude that a vehicle is in the corresponding parking space when there truly is no vehicle there. Another example, is that if trash bins, light posts, trees, sign posts, etc. are closely-adjacent the parking meter, almost any wireless vehicle detection scheme will be subjected to sufficient interferences from these, thereby causing the detector to make erroneous conclusions about the presence/absence of a vehicle in the parking space.

Even the sensor used to implement the vehicle detection suffers from its own respective drawbacks. For example, the use of RADAR (radio detection and ranging) suffers from such things as possible interferences from other RADAR-vehicle-detecting units, frequency band licensing concerns as well as cost. The use of optical sensors in vehicle detection (e.g., U.S. Pat. No. 4,043,117 (Maresca)) suffer from receiving reflections that may vary from strong reflections (reflected off of vehicle glass) versus weak reflections (reflected off the body of a very dark-colored vehicle), which are hard to detect. Videocamera/processing when used for vehicle detection (e.g., U.S. Pat. No. 5,777,951 (Mitschele et al.)) is not only very expensive but in those cases where the video camera is positioned to capture the front-end vehicle license plate, in those states where front-end vehicle license plates are not required, identification of the vehicle is thwarted. Thus, at present, use of ultrasonic sensors remains the most cost-effective means of detecting vehicles.

Prior art vehicle detecting parking meters utilizing a single ultrasonic sensor, such as those disclosed in U.S. Pat. Nos. 5,407,049 (Jacobs), 5,454,461 (Jacobs), U.S. Pat. No. 5,570,771 (Jacobs), U.S. Pat. No. 5,642,119 (Jacobs) and U.S. Pat. No. 5,852,411 (Jacobs et al.), which are assigned to the same assignee as the present invention, namely Intelligent Devices, Inc., operate where the ultrasonic sensor is energized with a pulse for emanating an interrogating signal towards the parking space and then the sensor waits to receive reflections. In particular, the reflections are examined to determine if they exceed a certain fixed threshold and, if so, the time measured between when the interrogating signal was sent until when the reflection was received is used to calculate a distance.

However, some of the problems with such a method are the following: certain vehicles disperse the interrogating signal, rather than returning a strong reflection; another problem is that to compensate for adjacent obstacles, e.g., crowned-street, tree, sign post, etc., the sensitivity of the sensor has to be reduced by raising the threshold but in doing so, even more vehicles are not properly detected; the reflected signals, or echos, are inherently unstable, i.e., the movement of air and even very minute physical movements in the environment make these signals unstable. Furthermore, some echos cancel other echos and exhibit multi-path problems, thus making the echos unstable.

Even where multiple ultrasonic sensors are used to detect vehicles, e.g., U.S. Pat. No. 3,042,303 (Kendall et al.); U.S. Pat. No. 3,046,519 (Polster); U.S. Pat. No. 3,046,520 (Polster); U.S. Pat. No. 3,105,953 (Polster); U.S. Pat. No. 5,263,006 (Hermesmeyer); U.S. Pat. No. 4,845,682 (Boozer et al.), or other objects U.S. Pat. No. 5,761,155 (Eccardt et al.), the design is that at least one sensor acts as an ultrasonic transmitter and the remaining sensors act as the ultrasonic receivers. As a result, there is no teaching or suggestion that each sensor act as both a transmitter/receiver for a signal that monitors a particular portion of the parking space. Furthermore, low power operation of these system is not a concern.

Another problem that is encountered with such vehicle detection systems is a "fast-parker" scenario, i.e., a vehicle pulling into a parking space that has just been emptied but before the vehicle detector has determined that the first vehicle has departed.

With regard to low power electronic parking meters, British Publication No. 2077475 discloses a low power electronic parking meter that operates using solar cells. Furthermore, since the sophisticated electronic parking meters which use microprocessors, electronic displays and IR/ultrasonic transducers consume too much power to operate by non-rechargeable batteries alone, U.S. Pat. No. 4,967,895 (Speas) discloses the use of solar power cells which charge capacitors or rechargeable batteries. However, various problems exist with the use of solar power sources including the use of parking meters in shady areas, or the use of parking meters during periods in which there is very little sunlight. This causes the rechargeable batteries to run down, and they require frequent replacement. Or, in the case of the use of capacitors, the lack of power causes the meter to become inoperative.

Therefore, there remains a need a system and method for providing any electronic parking meter with the ability to detect the presence or the absence of a vehicle in any existing parking meter space, independent of the surrounding environment, as reliably as possible and as inexpensively as possible while using a minimum of power.

OBJECTS OF THE INVENTION

Accordingly, it is the general object of this invention to provide an apparatus which addresses the aforementioned needs.

It is a further object of this invention to provide a vehicle detector unit in combination with a parking meter that reliably detects the presence or the absence of a vehicle positioned in the associated parking space.

It is still a further object of this invention to provide a vehicle detector unit in combination with a parking meter that detects the presence or the absence of a vehicle using an inexpensive detection scheme.

It is still yet a further object of this invention to provide a vehicle detector unit in combination with a parking meter that uses a minimum of power to reliably and inexpensively detect the presence or the absence of a vehicle in the associated parking space.

It is still yet another object of the present invention to provide a vehicle detector unit in combination with a parking meter that minimizes the number of false vehicle departures from, and the number of false vehicle arrivals to, the associated parking space.

It is a further object of this invention to provide a vehicle detector unit that digitizes all of the reflected signals.

It is yet another object of this invention to provide a vehicle detector unit that obtains a profile of the signal values recorded from the sensors that represents the condition of the corresponding parking space.

It is still yet another object of this invention to provide a vehicle detector unit that obtains a baseline electrical profile that represents an empty parking space.

It still yet even further another object of the present invention to provide vehicle detector unit that takes a series of readings of an empty parking space and which obtains the peak values from that series of readings.

It is still yet another object of the present invention to provide a vehicle detector unit that always compares the baseline empty parking space with the returned reflected signals when determining whether a vehicle is or is not in the parking space.

It is still another object of the present invention to provide a vehicle detector unit that seeks the highest values of the reflected signals.

It is still yet another object of the present invention to provide a vehicle detector unit that can detect when a person or object has been positioned in front of the sensor.

It is yet another object of this invention to provide a vehicle detector unit that provides any electronic parking meter with the ability to detect the presence or absence of vehicles in the corresponding parking space.

It is still another object of this invention to provide a vehicle detector unit that does not have to be precisely aimed in order to detect the presence or absence of vehicles in the corresponding parking space.

It is another object of this invention to provide a vehicle detector unit that provides any electronic parking meter with the ability to detect the presence or absence of vehicles in the corresponding parking space without the need to modify the hardware of the electronic parking meter.

It is a further object of this invention to provide a vehicle detector unit that provides any electronic parking meter with the ability to gather statistics on the parking space.

It is a further object of this invention to provide a vehicle detector unit that provides any electronic parking meter with the ability to zero the remaining time off the parking meter when the vehicle departs.

SUMMARY OF THE INVENTION

These and other objects of the instant invention are achieved by providing a vehicle detector unit for use with an electronic parking meter for detecting the presence or absence of a vehicle in a corresponding parking space. The unit comprises: a first signal emitting sensor positioned adjacent the corresponding parking space for transmitting a first signal towards the parking space in a first direction and for receiving a reflection of the first signal; a second signal emitting sensor positioned adjacent the corresponding parking space for transmitting a second signal towards the parking space in a second direction different from the first direction and for receiving a reflection of the second signal; and processing means coupled to the first and second signal-emitting sensors for processing the reflections of the first and second signals to determine if a vehicle is positioned in the corresponding parking space. The processor means is coupled to the electronic parking meter for communicating the presence or absence of a vehicle in the corresponding parking space to the electronic parking meter.

These and other objects of the present invention are also achieved by providing a method for detecting a vehicle at a parking space, The method comprising the steps of: (a) positioning two signal-emitting sensors adjacent the parking space and wherein the sensors are oriented toward the parking space; (b) alternately activating the two signal-emitting sensors, at a first predetermined interval, and wherein each of the two signal-emitting sensors both emit signals and receive reflections of the emitted signals to form a first set of reflected signals; (c) processing each of the reflected signals to determine if the amplitude of at least one of the first set of reflected signals is above a predetermined threshold; (d) alternately activating the two signal-emitting sensors at a second shorter predetermined interval to both emit signals and to receive reflections of the emitted signals to form a second set of reflected signals whenever the amplitude of at least one reflected signal of the first set of reflected signals exceeds the predetermined threshold; (e) processing each of the second set of reflected signals to determine if a predetermined number of consecutive reflected signals in the second set comprise amplitudes that exceed the predetermined threshold for establishing the presence of a vehicle in the parking space; and (f) transmitting a signal indicative of a vehicle detected.

DESCRIPTION OF THE DRAWINGS

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. **1** is an isometric view of the vehicle-side of the present invention;

FIG. **1**A is cross-sectional view of the present invention taken along lines **1**A—**1**A of FIG. **2**;

FIG. **2** is an elevated vehicle-side view of the present invention;

FIG. **3** is a view of the present invention taken along the lines **3**—**3** of FIG. **2**;

FIG. **4** is a view of the present invention taken along lines **4**—**4** of FIG. **2**;

FIG. **5** is a block diagram of the present invention;

FIG. **6** is a figure layout for FIGS. **6**A–**6**G;

FIG. **6**A is an electrical schematic of the vehicle detector unit voltage regulator circuit, a portion of the transducer interface circuit and an optional battery monitoring circuit;

FIG. **6**B is an electrical schematic of the other portion of the amplifier input circuit and the channel **1** transducer driver/listen circuit;

FIG. **6**C is an electrical schematic of the channel **2** transducer driver/listen circuit;

FIG. **6**D is an electrical schematic of the channel **3** transducer driver/listen circuit;

FIG. **6**E is an electrical schematic of the microcontroller of the vehicle detector unit;

FIG. **6**F is an electrical schematic of the multiplexer circuit for interfacing the three transducers to the microcontroller and of the vehicle detector unit memory;

FIG. **6**G is an electrical schematic of the optical tamper system;

FIG. **7** is a block diagram of the software of the present invention regarding the empty space mode and the car validation mode; and

FIG. **8** is a block diagram of the software of the present invention regarding the occupied space mode and the departure validation mode.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring now in greater detail to the various figures of the drawing wherein like reference characters refer to like parts, a vehicle detector unit (hereinafter "VDU") for use with electronic parking meters constructed in accordance with the present invention is shown generally at **316** in FIG. **1**. The VDU **316** issued in conjunction with a parking meter **10** to provide the parking meter **10** with vehicle detection capability. As shown most clearly in FIG. **1**, the parking meter **10** comprises a parking meter housing **12** that is supported at the parking space location (not shown) by a stanchion **14**. The parking meter housing **12** is coupled to the stanchion **14** via a vault **13** (which receives the deposited coins) and the VDU **316**.

The operative part of the parking meter, hereinafter known as the electronic parking meter (EPM) (see FIG. **5**; an example of such an EPM is the tool-less parking meter mechanism, TLPMM **20**, disclosed in A.S.N. 09/231,718 but it should be understood that any electronic parking meter would suffice) is positioned inside the housing **12**. A parking meter cover **15** having a lens portion **17** can only be removed by parking authority personnel only to obtain access to the EPM **20**. A top portion **21** of the EPM **20** can be seen through the lens portion **17**; three LEDs **50**A–**50**C mounted in the top portion **21** can be used for indicating various parking meter conditions to parking authority personnel.

As shown in FIG. **1**, which depicts the street-side of the parking meter **1** ONDU **316**, the VDU **316** comprises three ultrasonic transducers **321**, **322** and **323** that are specifically oriented to provide the widest and most reliable method of vehicle detection in the associated parking space (not shown). Each transducer has two angular orientations: a directional angle a and a tilt angle β. The directional angle a is that angle formed between a vertical plane VP and the transducer's axis (FIG. **4**). The tilt angle β is that angle formed between a horizontal plane HP and the transducer's axis. As used in this invention, the directional angle has a range of $-45° \leqq \alpha \leqq 45°$ (i.e., left or right, respectively, of the plane VP) and the tilt angle has a range of $-30° \leqq \beta 30°$ (i.e., above or below, respectively, of the plane HP). As an example, for parking meters used in the United States, the preferred directional angles and tilt angles are as follows: the outer transducers, namely transducers **321** and **323** are positioned 22½°(α) away from a vertical plane VP in opposite directions (FIG. **4**). In addition, all three transducers **321**–**323** are positioned 12°(β) downward from a horizontal plane HP (FIG. **3**). On the other hand, where different configurations of parking meters are used, e.g., where the VDU **316** is actually positioned close to the ground with the transducers' axes tilted upward rather than downward. As a result, the full scope of the associated parking space can be monitored for the presence/absence of a vehicle, even if the patron parks too far back in the space or too far front in the space, or parks very quickly just after a vehicle has departed, as will also be discussed in detail below. Furthermore, positioned over the central transducer **321** is an optical tamper sensor (also to be discussed later) that is located behind a plastic lens **324**.

One exemplary manner of establishing these specific angular orientations of the transducers **321**–**323** is by including a faceted projection **326** on the street-side of the VDU **316**. As shown most clearly in FIG. **1**, the outer transducers **322** and **323** are located on respective facets **328** and **330** which are constructed with the proper a orientation; the central transducer **321** is located in its corresponding facet **332**. All of the facets **328**–**332** are machined such that the cavity **334** (only one of which is shown in FIG. **3**) containing each transducer orients each transducer in the proper β orientation. It should be understood that the faceted projection **326** is exemplary only and that all other means known in the art for establishing the α and β transducer orientations are covered within the broadest scope of the invention.

The VDU **316** is secured between the parking meter housing **12** and the vault **13** using a plurality of bolts **48**A–**48**D (FIG. **1**A) that can only be accessed by parking meter personnel, such as disclosed in U.S. Pat. No. 5,852,411 (Jacobs et al.), assigned to the same Assignee of the present invention, namely Intelligent Devices, Inc., and which is incorporated by reference herein. As can be also seen in FIG. **1**A, the VDU **316** includes a coin passageway **336** for permitting the coins processed by the EPM **20** to pass through the VDU **316** and into the vault **13**. A printed circuit board (PCB) **338**, which contains the VDU electronics (FIGS. **6A–6G**) can also be seen in FIG. **1A**, as is discussed below.

A block diagram of the VDU **316** is shown in FIG. **5**. The VDU **316** comprises a microcomputer (μC) **340**, memory **342**, multiplexer **344**, the ultrasonic transducers **321–323** and an optical tamper system (OTS) **346**; the optical tamper system **346** forms one portion of a tamper system used in the VDU **316** that is discussed below. An electrical wire harness **348** comprises a first connector **350** and a second connector **352** that plug into respective mating connectors **70** (on the EPM **20**) and **354** on the VDU **316**. The wire harness **348** provides power (PWR, +6VDC) and ground (GND) from the EPM **20** as well as a reset line (RESET); the RESET line permits the both the EPM **20** and the VDU **316** to be simultaneously reset by parking meter personnel whenever they are doing maintenance on the EPM **20**. Furthermore, a "vehicle detected" line **356** and a "tamper" line **358** are also provided for passing a "vehicle-detected" status to the EPM **20** and a tamper status to the EPM **20**, respectively, as will be discussed in detail later.

The memory **342** stores the operational parameters of the VDU **316**. For example, the memory stores the baseline signals, (e.g., the transducer signals corresponding to an empty parking space, an optical signal of the OTS **346** corresponding to an unobstructed path towards the parking space), reference parameters, transducer frequency data, etc. In addition, the memory can be updated or modified through the EPM **20** via using the "vehicle-detected" line **356** and the "tamper" line **358**. In particular, when the baseline signals are obtained for each transducer **321–323**, parking meter personnel control that process via a hand-held unit (not shown) that communicates with the EPM **20** and ultimately with the VDU **316**.

The multiplexer **344** is used to reduce the amount of circuitry necessary for energizing the transducers **321–323** as well as amplifying the subsequent reflection signals in preparation for processing.

Each ultrasonic transducer **321–323** operates at a nominal frequency, e.g., 40 kHz. To ensure that all possible situations of environmental changes do not affect the vehicle is detection processing, the μC **340** excites the transducers **321–323** at a slightly higher and lower frequency around the nominal frequency. However, in the baseline case, to detect a vehicle at all, only the nominal frequency is monitored.

The μC **340** controls the activation of each of the transducers **321–323**. It should be understood that the phrase "activating a transducer" as used in this patent application means: (1) energizing the transducer; (2) listening for the reflection; and (3) processing the reflection by the μC **340** . By way of example, and not limitation, the energization phase is approximately 1 msec, the listening phase is approximately 28 msec and the processing phase is approximately 20 msec. Thus, "activating the transducer" is approximately a 50 msec process. Furthermore, transducer **321** is also referred to as channel **1**, transducer **322** is also referred to as channel **2** and transducer **323** is also referred to as channel **3**.

The detection methodology basically comprises four modes: (1) empty space mode; (2) car validation mode (aggressive mode); (3) occupied space mode and (4) vehicle departure (hypermode).

In the empty space mode (FIG. **7**), the μC **340** activates the transducers in a specific sequence: channel **1**, channel **2**, channel **1** and channel **3** and whereby each channel is activated only once per second. This permits the entire parking space to be accurately monitored while using as little VDU **316** power as possible.

It should be noted that by using this "outer-center-outer-center" activation scheme the central channel, i.e., transducer **321**, is being activated every other time since the center transducer **321** tends to detect most vehicles parked in the corresponding parking space. Furthermore, this "outer-center-outer-center" activation scheme is used only during the empty space mode.

Once one of the channels has detected a return signal above a predetermined threshold (e.g., the noise level), the μC **340** institutes the car validation, or aggressive, mode whereby the transducers **321–323** are activated much more rapidly, e.g., channels **1**, **2** and **3** are sequentially activated (150 msec total) and then remain silent for approximately 350 msec and then channels **1**, **2** and **3** are again sequentially activated for another 150 msec followed by another period of silence for the remaining 350 msec. This mode is repeated. If any channel detects a predetermined number (e.g., four) of consecutive return signals above the predetermined threshold above the noise level, then a vehicle is detected. Furthermore, the particular channel that experienced the best above-threshold signal is designated the "favored channel".

Once a car is validated, the μC **340** institutes the occupied space mode whereby the favored channel is activated only once every second. This mode verifies the vehicle's continued presence while using as little VDU **316** power as possible.

If the favored channel signal terminates, the μC **340** institutes the vehicle departure, or hypermode. In this mode, the μC **340** activates the transducers **321–323** much more rapidly, e.g., channels **1**, **2** and **3** are sequentially activated (150 msec total) twice a second and then remain silent for the remainder of the second (approximately 700 msec). This mode is repeated. If all three channels experience a predetermined number (e.g., six) of consecutive "no return signals", then the vehicle has departed. The μC **340** then returns to the empty space mode. If, on the other hand, this predetermined number of consecutive "no return signals" is not achieved, e.g., the favored channel signal returns, or a new favored channel is established, then the μC **340** returns to the occupied space mode. This "re-establish" operation is important in that intermittent conditions, e.g., snow, rain, etc., that may partially block the ultrasonic transducers **321–323** do not prevent the VDU **316** from continuing to re-establish detection of a parked vehicle.

The VDU **316** electronics are discussed next. It should be noted that Table 1 below contains exemplary part numbers for the various electrical components used in the VDU **316**. It should be understood that these components are listed for example only and that the VDU **316** is not limited, in any manner, to only those components.

FIG. **6A** depicts a voltage regulator circuit **360** that converts the +6VDC from the EPM **20** into +4VDC for use with the other VDU electronics. Also, a provisional circuit **362** is available for measuring battery voltage or otherwise providing circuitry for supporting a warning indicator as to low battery power.

Each transducer **321–323** has its own transducer driver/listen circuit that is selectively activated by the μC **340** through the multiplexer **344** (FIG. **6F**). However, there is only one reflected-signal amplification (RSA) circuit **359** (FIGS. **6A–6B**) that is selectively connected, through the multiplexer **344**, to the transducer that has been activated.

The RSA circuit **359**, which ultimately transmits the reflected signal to the μC **340** (pin RA**0**/AN**0**) for processing, amplifies the reflected signal in preparation for the processing. In particular, the driver/listen circuit **361** for channel **1** (transducer **321**) is shown in FIG. **6**B the driver/listen circuit **362** for channel **2** (transducer **322**) is shown in FIG. **6**C; and the driver listen circuit **363** for channel **3** (transducer **323**) is shown in FIG. **6**D.

The driver path in each channel comprises the transformer T1 (T2 for channel **2**, and T3 for channel **3**) which is energized whenever the transistor Q3 (Q5 for channel **2** and Q8 for channel **3**) is biased on by the μC **340**. This energizes the respective transducer for emitting the 1 msec ultrasonic signal pulse. Once emitted, the transducer then "listens" for the reflection. The listen path in each channel comprises the LM6134 amplifier coupled to the driver circuit. In particular, with regard to channel **1**, the listen path is through R**14**, R**21** and C**14** into the LM6134; with regard to channel **2**, the listen path is through R**52**, R**51** and C**29** into the LM6134; and with regard to channel **3**, the listen path is through R**56**, R**55** and C**30** into the LM6134. The output of each LM6134 is selectively coupled, through the multiplexer **344**, to the RSA circuit **359**. In particular, whichever channel is activated, the channel output from the corresponding listen circuit (CH**1**, CH**2** or CH**3** shown in FIGS. **6**B, **6**C and **6**D, respectively,) is routed, through the multiplexer **344**, to the AMP IN input of the RSA circuit **359**, as shown in FIG. **6**B. Thus, the reflected signal received by the activated channel is processed by the μC **340**, which includes digitizing the received reflected signal. The gain of the RSA circuit **359** can adjusted by the μC **340** as shown the GAIN input in FIG. **6**A which is connected to pin RB**5** of the μC **340** (FIG. **6**E).

As discussed previously, the VDU **316** electronics can be reset automatically whenever the EPM **20** is reset via the RESET line. In the alternative, if parking authority personnel need to reset the VDU **316** directly, there is a manually-operated switch SW (FIG. **6**E) that can momentarily depressed.

It should be understood that the embodiment disclosed herein is exemplary only is and that other components having higher resolution could be substituted herewith. However, bearing in mind that minimum power must be used since the parking meter **10** is a stand-alone unit, the above-described embodiment utilizes an 8-bit microcontroller (Microchip's PIC16C73-10I/P) for μC **340**.

The sampling rate of the μC **340** is 3 samples/msec. Since sound travels at approximately 1 ft/msecand since onlythe return trip of the reflected signal is required (i.e., time of flight/2), in order to properly monitor a vehicle target region of 0–14 feet requires 6 samples/ft. Therefore, each activation of any transducer **321**–**323** results in 84 samples being temporarily stored in the μC **340** for processing. When the parking meter **10** is first installed, the baseline signal (i.e., the reflected signal corresponding to an empty parking space) for each of the transducers **321**–**323** is obtained and, as a result, three groups of 84 samples are stored in the memory **342**.

Within the vehicle target region of 0–14 feet, the range of 2–10 feet is considered the vehicle region. When the processor analyzes the received samples, it looks for those samples having the highest values that exceed the predetermined thresholds (which are modifiable by parking meter personnel through a hand-held programming unit, not shown, and the EPM **20**). These thresholds comprise values (e.g., 20 counts) above the baseline signals.

The Tamper System

One of the important features of the present invention is the tamper system incorporated into the VDU **316**. The tamper system basically comprises three parts: (1) the optical tamper system (OTS) **346** (FIG. **6**G); (2) the μC **340** monitoring of each channel for a significant decrease in the amplitude of the reflected ultrasonic signal (something touching the sensor) corresponding to a close range; and (3) the μC **340** monitoring of each channel for a significant increase in the amplitude (someone or something standing close to the transducer) of the ultrasonic signal corresponding to a close range.

The purpose of the OTS **346** is to provide an independent check on the ultrasonic transducers **321**–**323** when the ultrasonic transducers detect that a car may be departing (i.e., the favored channel return signal has terminated-see FIG. **8**). If something/someone inadvertently or intentionally began diverting the ultrasonic transducer signal from the favored channel, there would be no returned reflected signal which would be interpreted by the μC **340** as an empty parking space. To verify this, the μC **340** activates the OTS **346** once per second which sends out its own optical (e.g., infrared) signal. If the parking space is truly vacated, there will be no returned optical signal and the output of the OTS detector (discussed below) sent to the μC **340** will not differ from the baseline OTS characteristic. If, on the other hand, something/someone is inadvertently or intentionally blocking the favored channel signal while a vehicle is parked in the corresponding parking space, the OTS detector will detect a returned optical signal that the μC **340** will determine is greater than the baseline OTS characteristic and, as a result, will set the "tamper line" **358**. As long as the returned optical signal is greater than the baseline OTS characteristic, the μC **340** maintains the tamper line **358** set. Once the returned optical signal is restored back to the baseline OTS characteristic, the μC **340** will reset the tamper line **358**.

In particular, as shown in FIG. **6**G, the OTS **346** includes an infrared LED D**13** and an infrared photodiode D**14** which are located behind the plastic lens **324** (FIG. **1**). These two components are physically positioned behind the lens to be pointed outward such that during normal operation, internal reflections of light from the LED D**13** to the photodiode D**14** are kept to a minimum. Furthermore, as shown in FIG. **3**, the LED D**13** and photodiode D**14** are positioned 12°(β) downward from a horizontal plane HP. The LED D**13** and its connecting circuits are hereinafter referred to as the emitter **364** and the photodiode D**14** and its connecting circuits are hereinafter referred to as the detector **366**. The OTS **346** is activated once per second only when there is a vehicle in the corresponding parking space and when the ultrasonic transducers detect that the car may be departing (i.e., the favored channel return signal has terminated-see FIG. **8**). It should be understood that the the tilt angle β of the LED D**13** and photodiode D**14** can be in the same tilt angle range discussed earlier with respect to the transducers **321**–**323**, namely $-30°<\beta<30°$ with the preferred β being 12°.

Assuming that the favored channel signal has been lost, operation of the OTS **346** is as follows: First, the μC **340** turns on the detector **366** by using the OPTO-AMP signal to permit the detector **366** to settle down. Second, the μC **340** turns on the OPTO-LED signal for 10 μsec to pulse the emitter **364**. The AC coupling (C**23** and R**34**) in the detector **366**, forms a synchronous detection, which acts to filter out the ambient light (i.e., sunlight, car headlights, etc.) so that, if a reflected optical signal were to be detected by the detector **366**, it would have to be the reflection of the 10 μsec pulse only.

If something or someone were to completely cover the plastic lens **324** during this potential vehicle departing stage, the internal reflections of the LED D**13** will be maximized since the photodiode D**14** would then be detecting all of the light emanating from LED D**13**. As a result, the detector **366** output will be greater than the baseline OTS characteristic and the μC **340** will again set the tamper line **358** for as long as that condition occurs.

In addition to the OTS **346**, the tamper system of the VDU **316** also includes monitoring the reflected ultrasonic sensor signals corresponding to a close range (e.g., <2 ft). During the processing of each of these close range ultrasonic signals, the μC **340** monitors whether there has been either a significant increase/decrease in the return signal amplitude. A significant increase in the return signal amplitude over the baseline indicates that something or someone has entered into the lower end of the vehicle target region (0–2 ft), within a minimum threshold distance (e.g., ≦1 foot) of the parking meter that indicates that the thing or person cannot be a vehicle since it is too close. A significant decrease in the return signal amplitude indicates that something is contacting or has been placed over the transducer (e.g., a piece of tape, chewing gum, etc.) since such contact actually inhibits the vibration of the ultrasonic sensor. Either of these events, in addition to the OTS **346** detecting a tamper condition (described above), signals to the μC **340** that the ultrasonic transducers **321–323** are being tampered with and therefore, the μC **340** will set the tamper line **358**.

It should be understood that what is meant by the term "significant" can vary depending upon the type of processing means being used. For example, in the present invention using an 8-bit μC **340**, a typical baseline corresponding to an empty space may be 70 counts/255 and therefore a difference of ±10–20 counts from that baseline would be considered a "significant" increase/decrease in the return signal. Where higher resolution devices are used (e.g., 10-bit or 16-bit processing means), the above values would differ. Thus, the above values given for significant increases/decreases over the baseline are by way of example only and are not meant to limit the scope of the tamper system of the present invention in any way.

The EPM **20** can use this tamper line **358** set to enter a passive mode whereby the EPM **20** is no longer relying on the vehicle detection data from the VDU **316**; instead, the EPM **20** acts like a conventional parking meter by continuing to count down the time remaining on the meter. This prevents someone from trying to zero the time off of the EPM **20** while a vehicle is parked by tampering with the ultrasonic sensors **321–323**. Once the tampering is terminated, the VDU **316** again begins its vehicle detection routine and normal operation is restored.

As stated earlier, the RESET line is provided so that the parking authority personnel can reset the VDU **316** at the same time that they set the EPM **20**. In particular, the EPM **20** may comprise an internal reset switch. Whenever, the parking authority personnel reset the EPM **20** (e.g., when replacing the batteries in the EPM **20**), the internal reset switch in the EPM **20** is activated and both the EPM **20** and VDU **316** are reset. Other than that, the RESET line is not used during normal operation.

It has been established through testing that the center transducer **321** is the most likely transducer to detect a vehicle parked in the corresponding parking space. Furthermore, the use of three channel monitoring methodology described in detail above permits the proper operation of vehicle detection while remaining unaffected by any parking meter installation variations. For example, should the installation personnel not exactly orient the street side of the VDU **316** at the corresponding parking space, the three channel monitoring will still reliably detect the vehicle in the parking space. The detection methodology used in the VDU **316** described above is designed for detecting the "quick-parker" so that even when a vehicle is able to park in the parking space just evacuated by another vehicle, the VDU **316** is able to accurately detect the first vehicle departure, inform the EPM **20**, and then immediately detect the entrance of a new vehicle into the parking space. In addition, the detection methodology used in the VDU **316** is also designed for detecting vehicles parked too far forward in the parking space or too far back in the parking space.

Another embodiment of the VDU **316** uses only two ultrasonic transducers. FIG. **1A**, depicts a two transducer configuration whereby the central transducer **321** has been eliminated. In all other respects, the hardware and software operation of this second embodiment of the VDU remains the same. For example, the α and β orientations of the ultrasonic sensors **322** and **323** remain the same; the four detection modes are still used except that the"outer-center-outer-center" activation scheme in the empty space mode is simply between channel **2** and channel **3**. The disadvantage of the 2-transducer electronic parking meter is that the parking meter/VDU installation must be very precise or else the detection method will not work. Assuming it is installed properly, the software works the same way as with the three transducers.

Without further elaboration, the foregoing will so fully illustrate our invention that others may, by applying current or future knowledge, readily the same for use under various conditions of service.

TABLE 1

ITEM	DESCRIPTION	MANUFACTURER	PART NO.
C1	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF50V
C2	Tantalum Capacitor	Kemet	4.7UF 16V
C3	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C4	Tantalum Capacitor	Kemet	10UF 6V
C5	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C6	Ceramic Chip Capacitors 0805 5%	Murata GRM40	33P 50V
C7	Ceramic Chip Capacitors 0805 5%	Murata GRM40	33P 50V
C9	Tantalum Capacitor	Kemet	10UF 6V
C10	Tantalum Capacitor	Kemet	4.7UF 16V
C10A	Electrolytic Cap 470UF 10 V	Panasonic	ECE-A1AU471
C11	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C12	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
C13	Tantalum Capacitor	Kemet	10UF 6V
C14	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01 UF 50V
C15	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
C16	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01 UF 50 V
C17	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50 V
C18	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01UF 50V
C19	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
C20	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01UF 50V

TABLE 1-continued

ITEM	DESCRIPTION	MANUFACTURER	PART NO.
C21	Tantalum Capacitor	Kemet	4.7UF 16V
C22	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C23	Ceramic Chip Capacitors 0805 5%	Murata GRM40	330P 50V
C24	Ceramic Chip Capacitors 0805 5%	Murata GRM40	47P 50V
C26	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C27	Electrolytic Cap 470UF 10V	Panasonic	ECE-A1AU471
C28	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
C29	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01UF 50V
C30	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.01UF 50V
C31	Ceramic Chip Capacitors 0805 5%	Murata GRM40	0.1UF 50V
C32	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
C33	Ceramic Chip Capacitors 0805 5%	Murata GRM40	100P 50V
CN1	Power Connector for Spacer	Molex	22-11-2052
CN2	Connector for Ultrasonic Transducers	Molex	22-11-2062
CN3	Connector for IR Tamper Detect	Molex	22-11-2042
D2	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D3	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D4	Dual Diode-Small Signal	Fairchild Or EQ	BAV99
D5	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D7	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D8	Diode-Small Signal	Fairchild Or EQ	MMBD914LT1
D9	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D10	Zener Diode SOT23	Fairchild Or EQ	MMBZ5245B
D11	Dual Diode-Small Signal	Fairchild Or EQ	BAV99
D12	Dual Diode-Small Signal	Fairchild Or EQ	BAV99
D13	LED	II Stanley	DN304
D14	Photodiode	Siemens	SFH203FA
IC1	Microcomputer	Microchip	PIC16C73-10I/P
IC2	EEPROM	Microchip	24LC04-I/SN
IC4	Quad Op Amp	National Or EQ	LM6134BIM
IC5	Dual Op Amp	Analog Devices	AD8032AR
IC6	Voltage Divider	TI	TLE2426ID
IC7	Dual 4 Line Mux	Fairchild Or EQ	MM74HC4052M
IC8	Quad Op Amp	National Or EQ	LM6134BIM
PCB1	Printed Circuit Board-2 sided 6 × 4 in.		
P1	Plug for Veh Det Side of Cable	Molex	22-01-3057
	Pins for Above (5)	Molex	08-55-0102
P2	Plug for Meter Side of Cable	Amp	87631-2
	Pins for Above (5)	Amp	102128-1
P3	Plug for Ultrasonic Transducers	Molex	22-01-3067
	Pins for Above (6)	Molex	08-55-0102
P4	Plug for IR Tamper Detect	Molex	22-01-3047
	Pins for Above (4)	Molex	08-55-0102
Cable	5 Conductor Jacketed Cable - 20 inches	Alpha Wire Corp	1175C
Q3	Transistor-NPN	Zetex	FMMT491
Q4	Small Signal Transistor-PNP	Fairchild Or EQ	MMBR4403LT1
Q6	Transistor - NPN	Zetex	FMMT489
Q5	Transistor - NPN	Zetex	FMMT491
Q7	Small Signal Transistors-NPN	Fairchild Or EQ	MMBR4401LT1
Q8	Transistor-NPN	Zetex	FMMT491
R1	Resistor 0805 SMD 5%	Dale CRCW-0805	4.7K

TABLE 1-continued

ITEM	DESCRIPTION	MANUFACTURER	PART NO.
R2	Resistor 0805 SMD 5%	Dale CRCW-0805	4.7K
R12	Resistor 0805 SMD 5%	Dale CRCW-0805	10
R13	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R14	Resistor 0805 SMD 5%	Dale CRCW-0805	2K
R15	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R16	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R18	Resistor 0805 SMD 5%	Dale CRCW-0805	47K
R20	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R21	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R22	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R23	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R24	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R25	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R26	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R27	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R27	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R29	Resistor 0805 SMD 5%	Dale CRCW-0805	100
R30	Resistor 0805 SMD 5%	Dale CRCW-0805	2.2
R31	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R32	Resistor 0805 SMD 5%	Dale CRCW-0805	100K
R33	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R34	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R35	Resistor 0805 SMD 5%	Dale CRCW-0805	33K
R36	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R37	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R38	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R38	Resistor 0805 SMD 5%	Dale CRCW-0805	33K
R40	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R42	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R43	Resistor 0805 SMD 5%	Dale CRCW-0805	8.2K
R46	Resistor 0805 SMD 5%	Dale CRCW-0805	2K
R47	Resistor 0805 SMD 5%	Dale CRCW-0805	3.9K
R48	Resistor 0805 SMD 5%	Dale CRCW-0805	8.2K
R50	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R51	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R52	Resistor 0805 SMD 5%	Dale CRCW-0805	2K
R54	Resistor 0805 SMD 5%	Dale CRCW-0805	1K
R55	Resistor 0805 SMD 5%	Dale CRCW-0805	1K

TABLE 1-continued

ITEM	DESCRIPTION	MANUFACTURER	PART NO.
R56	Resistor 0805 SMD 5%	Dale CRCW-0805	2K
R57	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R58	Resistor 0805 SMD 5%	Dale CRCW-0805	20K
R59	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
R60	Resistor 0805 SMD 5%	Dale CRCW-0805	10K
S1	Reset Switch	Panasonic	EVQ-PBC09K
T1	Transformer	Datatronics	REF 21817
T2	Transformer	Datatronics	REF 21817
T3	Transformer	Datatronics	REF 21817
U1	Ultrasonic Transducer	APC	APC40T/R-16E
U2	Ultrasonic Transducer	APC	APC40T/R-16E
U3	Ultrasonic Transducer	APC	APC40T/R-16E
VR1	Voltage Regulator	Seiko Telcom	S81240PG TC55RP4002 ECB713
X1	9.8304 MHZ Crystal	Mtron	
Z1	Zero Ohm Jumper 0895	Dale CRCW-0805	
Z3	Zero Ohm Jumper 0805	Dale CRCW-0805	
Z4	Zero Ohm Jumper 0805	Dale CRCW-0805	

We claim:

1. A vehicle detector unit for use with an electronic parking meter for detecting the presence or absence of a vehicle in a corresponding parking space, said unit comprising:

a first signal emitting sensor positioned adjacent the corresponding parking space for transmitting a first signal towards the parking space in a first direction and for receiving a reflection of said first signal;

a second signal emitting sensor positioned adjacent the corresponding parking space for transmitting a second signal towards the parking space in a second direction different from said first direction and for receiving a reflection of said second signal;

processing means coupled to said first and second signal-emitting sensors for processing said reflections of said first and second signals to determine if a vehicle is positioned in the corresponding parking space, said processor means coupled to the electronic parking meter for communicating the presence or absence of a vehicle in the corresponding parking space to the electronic parking meter;

means for storing a first reflected signal corresponding to an empty parking space for said first signal-emitting sensor and a second reflected signal corresponding to the empty parking space for said second signal-emitting sensor, said storing means being coupled to said processing means; and

a tamper detection system, said tamper detection system being coupled to said processing means for detecting inadvertent or intentional tampering of said first or second signal-emitting sensors.

2. The vehicle detector unit of claim **1** wherein tamper detection system comprises an optical signal emitter and detector coupled to said processor means, said optical signal emitter and detector being positioned toward the corresponding parking space.

3. The vehicle detector unit of claim **2** wherein said means for storing includes a reflected signal corresponding to an unobstructed path towards the corresponding parking space for said optical signal emitter.

4. The vehicle detector unit of claim **2** wherein the optical signal emitter and detector comprise an infrared light emitting diode and an infrared photodetector.

5. The vehicle detector unit of claim **1** further comprising a housing having a side which is positioned towards the corresponding parking space, said side including said first and second signal-emitting sensors at a first angular orientation and a second angular orientation, respectively, said first angular orientation being in the range of 0–45 degrees away from a vertical plane through said side and said second angular orientation being in the range of 0–45 degrees in the opposite direction of said first angular orientation from said vertical plane.

6. The vehicle detector unit of claim **5** wherein said first and second signal-emitting sensors are positioned at an angular orientation in the range of −30 to 30 degrees from a horizontal plane.

7. The vehicle detector unit of claim **1** further comprising a housing having a side which is positioned towards the corresponding parking space, said side including said first and second signal-emitting sensors at a first angular orientation and a second angular orientation, respectively, said first angular orientation being 22½ degrees away from a vertical plane through said side and said second angular orientation being 22½ degrees in the opposite direction of said first angular orientation from said vertical plane.

8. The vehicle detector unit of claim **7** wherein said first and second signal-emitting sensors are positioned downward from a horizontal plane at an angular orientation of 12 degrees.

9. The vehicle detector unit of claim **8** further comprising means for storing a first reflected signal corresponding to an empty parking space for said first signal-emitting sensor and a second reflected signal corresponding to the empty parking space for said second signal-emitting sensor, said storing means being coupled to said processing means.

10. The vehicle detector unit of claim **9** further comprising a tamper detection system, said tamper detection system coupled to said processing means for detecting inadvertent or intentional tampering of said first or second signal-emitting sensors.

11. The vehicle detector unit of claim **10** wherein tamper detection system comprises an optical signal emitter and detector coupled to said processor means, said optical signal emitter and detector being positioned toward the corresponding parking space.

12. The vehicle detector unit of claim **11** wherein said optical signal emitter and emitter are positioned between said first and second signal-emitting means and wherein said emitter and detector are positioned at an angular orientation in the range of −30 to 30 degrees from said horizontal plane.

13. The vehicle detector unit of claim **11** wherein said optical signal emitter and emitter are positioned between said first and second signal-emitting means and wherein said emitter and detector are positioned downward from said horizontal plane at said angular orientation of 12 degrees.

14. The vehicle detector unit of claim **11** wherein said means for storing includes a reflected signal corresponding to an unobstructed path towards the corresponding parking space for said optical signal emitter.

15. A vehicle detector unit for use with an electronic parking meter for detecting the presence or absence of a vehicle in a corresponding parking space, said unit comprising:

a first signal emitting sensor positioned adjacent the corresponding parking space for transmitting a first signal towards the parking space in a first direction and for receiving a reflection of said first signal;

a second signal emitting sensor positioned adjacent the corresponding parking space for transmitting a second signal towards the parking space in a second direction different from said first direction and for receiving a reflection of said second signal; and

processing means coupled to said first and second signal-emitting sensors for processing said reflections of said first and second signals to determine if a vehicle is positioned in the corresponding parking space, said processor means coupled to the electronic parking meter for communicating the presence or absence of a vehicle in the corresponding parking space to the electronic parking meter;

a third signal-emitting sensor, positioned in between said first and second signal-emitting sensors, for transmitting a third signal towards the parking space in a third direction, different from said first and second directions and for receiving a reflection of said third signal, said third signal-emitting means being coupled to said processing means;

wherein said processing means processes said reflection of said third signal, in addition to processing said reflections of said first and second signals, to determine if a vehicle is positioned in the corresponding parking space;

said first direction being towards a front portion of the corresponding parking space, said second direction being towards a back portion of the corresponding parking space and said third direction being towards a center portion of the corresponding parking space;

means for storing a first reflected signal corresponding to an empty parking space for said first signal-emitting sensor, a second reflected signal corresponding to the empty parking space for said second signal-emitting sensor and a third reflected signal corresponding to the empty parking space for said third signal-emitting sensor, said storing means being coupled to said processing means; and

a tamper detection system, said tamper detection system being coupled to said processing means for detecting inadvertent or intentional tampering of said first, second and third signal-emitting sensors.

16. The vehicle detector unit of claim **15** wherein tamper detection system comprises an optical signal emitter and detector coupled to said processor means, said optical signal emitter and detector being positioned toward the corresponding parking space and positioned above said third signal-emitting sensor.

17. The vehicle detector unit of claim **16** wherein said means for storing includes a reflected signal corresponding to an unobstructed path towards the corresponding parking space for said optical signal emitter.

18. The vehicle detector unit of claim **15** further comprising a housing having a side which is positioned towards the corresponding parking space, said side including said first and second signal-emitting sensors at a first angular orientation and a second angular orientation, respectively, said first angular orientation being in the range of 0–45 degrees away from a vertical plane through said side and said second angular orientation being in the range of 0–45 degrees in the opposite direction of said first angular orientation from said vertical plane.

19. The vehicle detector unit of claim **15** further comprising a housing having a side which is positioned towards the corresponding parking space, said side including said first and second signal-emitting sensors at a first angular orientation and a second angular orientation, respectively, said first angular orientation being 22½ degrees away from a vertical plane through said side and said second angular orientation being 22½ degrees in the opposite direction of said first angular orientation from said vertical plane.

20. The vehicle detector unit of claim **19** wherein said first, second and third signal-emitting sensors are positioned at an angular orientation in the range of −30 to 30 degrees from a horizontal plane.

21. The vehicle detector unit of claim **19** wherein said first, second and third signal-emitting sensors are positioned downward from a horizontal plane at an angular orientation of 12 degrees.

22. The vehicle detector unit of claim **19** further comprising means for storing a first reflected signal corresponding to an empty parking space for said first signal-emitting sensor, a second reflected signal corresponding to the empty parking space for said second signal-emitting sensor and a third reflected signal corresponding to the empty parking space for said third signal-emitting sensor, said storing means being coupled to said processing means.

23. The vehicle detector unit of claim **22** further comprising a tamper detection system, said tamper detection system coupled to said processing means for detecting inadvertent or intentional tampering of said first, second or third signal-emitting sensors.

24. The vehicle detector unit of claim **23** wherein tamper detection system comprises an optical signal emitter and detector coupled to said processor means, said optical signal emitter and detector being positioned toward the corresponding parking space.

25. The vehicle detector unit of claim **24** wherein said optical signal emitter and emitter are positioned above said third signal-emitting means and wherein said emitter and detector are positioned at an angular orientation in the range of −30 to 30 degrees from said horizontal plane.

26. The vehicle detector unit of claim **24** wherein said optical signal emitter and emitter are positioned above said third signal-emitting means and wherein said emitter and detector are positioned downward from said horizontal plane at said angular orientation of 12 degrees.

27. The vehicle detector unit of claim **26** wherein said means for storing includes a reflected signal corresponding to an unobstructed path towards the corresponding parking space for said optical signal emitter.

28. A method for detecting a vehicle at a parking space, said method comprising the steps of:

(a) positioning two signal-emitting sensors adjacent the parking space, said sensors being oriented toward the parking space;

(b) alternately activating said two signal-emitting sensors, at a first predetermined interval, each of said two signal-emitting sensors both emitting signals and receiving reflections of said emitted signals to form a first set of reflected signals;

(c) processing each of said reflected signals to determine if the amplitude of at least one of said first set of reflected signals is above a predetermined threshold;

(d) alternately activating said two signal-emitting sensors at a second shorter predetermined interval to both emit signals and to receive reflections of said emitted signals to form a second set of reflected signals whenever the amplitude of at least one reflected signal of said first set of reflected signals exceeds said predetermined threshold;

(e) processing each of said second set of reflected signals to determine if a predetermined number of consecutive reflected signals in said second set comprise amplitudes that exceed said predetermined threshold for establishing the presence of a vehicle in the parking space; and

(f) transmitting a signal indicative of a vehicle detected.

29. The method of claim **28** wherein said step of positioning two signal-emitting sensors adjacent the parking space comprises:

(a) clearing the parking space on a one-time basis to form an empty parking space;

(b) activating each of said two signal-emitting sensors alternately at said first predetermined interval to establish a baseline signal for each of said two signal-emitting sensors on a one-time basis;

(c) storing each of said respective baseline signals in a storage means for use in said step of processing each of said second set of reflected signals.

30. The method of claim **29** further comprising the steps of:

(a) selecting one of said two signal-emitting sensors that received a signal in said second set of reflected signals having the highest amplitude; and

(b) activating only said selected one of said two signal-emitting sensors at said first predetermined interval to form a third set of reflected signals.

31. The method of claim **30** further comprising the steps of:

(a) alternately activating said two sensors at a third predetermined interval whenever said third set of signals disappear to determine if a parked vehicle has departed;

(b) terminating the transmission of said signal indicative of a vehicle detected whenever said two sensors experience a predetermined number of consecutive no receipt of reflected signals from said alternate activation of said two sensors at said third predetermined interval.

32. The method of claim **31** further comprising the steps of:

(a) positioning an optical signal sensor adjacent the parking space and orienting it toward the parking space;

(b) activating said optical signal sensor on a one-time basis while the parking space is empty to obtain a baseline signal for said optical signal-emitting sensor;

(c) storing said optical sensor baseline signal in a storage means;

(d) activating said optical sensor at said first predetermined interval to generate optical signal reflections whenever said third set of signals disappear;

(e) comparing said optical signal reflections to said optical sensor baseline to determine if a tamper condition is present; and

(f) transmitting a signal indicative of a tamper condition whenever the amplitude of said optical signal reflections is greater than said optical sensor baseline.

33. The method of claim **32** wherein said optical sensor comprises an infrared emitter and an infrared detector.

34. The method of claim **30** further comprising the steps of:

(a) alternately activating said two sensors at a third predetermined interval whenever said third set of signals disappear to determine if a parked vehicle has departed;

(b) monitoring the change in amplitude of any reflected signals from said alternate activation of said two sensors at said third predetermined interval that correspond to a predetermined range away from said at least two signal-emitting sensors; and

(c) transmitting a signal indicative of a tamper condition whenever said change in amplitude is greater than a second predetermined threshold or less than a third predetermined threshold.

35. The method of claim **28** wherein said step of positioning two signal-emitting sensors comprises orienting said at least two signal-emitting sensors in opposite directions at an angle in the range of 0 to 45 degrees from a vertical plane.

36. The method of claim **28** wherein said step of positioning two signal-emitting sensors comprises orienting said at least two signal-emitting sensors in opposite directions at an angle of 22½ degrees from a vertical plane.

37. The method of claim **36** wherein said step of positioning a third signal-emitting sensor between said two signal-emitting sensors comprises orienting all of said signal-emitting sensors at an angular orientation in the range of −30 to 30 degrees from a horizontal plane.

38. The method of claim **36** wherein said step of positioning a third signal-emitting sensor between said two signal-emitting sensors comprises orienting all of said signal-emitting sensors downward at an angle of 12 degrees from a horizontal plane.

39. The method of claim **36** wherein said step of positioning two signal-emitting sensors comprises orienting said two signal-emitting sensors at an angular orientation in the range of −30 to 30 degrees from a horizontal plane.

40. The method of claim **36** wherein said step of positioning two signal-emitting sensors comprises orienting said two signal-emitting sensors downward at an angle of 12 degrees from a horizontal plane.

41. The method of claim **28** further comprising the step of positioning a third signal-emitting sensor between said two signal-emitting sensors.

42. The method of claim **41** further comprising the steps of:

(a) modifying said step of alternately activating said two signal-emitting sensors by alternately:

(1) activating one of said two signal-emitting sensors;

(2) activating said third signal-emitting sensor;

(3) activating the other one of said two signal-emitting sensors;

(4) activating said third signal-emitting sensor;

(5) repeating sensor sequencing steps (1)–(4) at said first predetermined interval to generate said first set of reflected signals; and

(b) modifying said step of alternately activating said two signal emitting sensors at said second shorter predetermined interval by alternately and sequentially activating said three sensors at said second shorter predetermined interval to form said second set of reflected signals.

43. The method of claim **42** wherein said step of positioning a third signal-emitting sensor adjacent the parking space comprises:

(a) clearing the parking space on a one-time basis to form an empty parking space;

(b) activating each of said three signal-emitting sensors alternately at said first predetermined interval to establish a baseline signal for each of said three signal-emitting sensors on a one-time basis;

(c) storing each of said respective baseline signals in a storage means for use in said step of processing each of said second set of reflected signals.

44. The method of claim **43** further comprising the steps of:

(a) selecting one of said three signal-emitting sensors that received a signal in said second set of reflected signals having the highest amplitude; and

(b) activating only said selected one of said three signal-emitting sensors at said first predetermined interval to form a third set of reflected signals.

45. The method of claim **44** further comprising the steps of:

(a) alternately activating said three sensors at a third predetermined interval whenever said third set of signals disappear to determine if a parked vehicle has departed;

(b) terminating the transmission of said signal indicative of a vehicle detected whenever said three sensors experience a predetermined number of consecutive no receipt of reflected signals from said alternate activation of said three sensors at said third predetermined interval.

46. The method of claim **45** further comprising the steps of:

(a) positioning an optical signal sensor adjacent the parking space and orienting it toward the parking space;

(b) activating said optical signal sensor on a one-time basis while the parking space is empty to obtain a baseline signal for said optical signal-emitting sensor;

(c) storing said optical sensor baseline signal in a storage means;

(d) activating said optical sensor at said first predetermined interval to generate optical signal reflections whenever said third set of signals disappear;

(e) comparing said optical signal reflections to said optical sensor baseline to determine if a tamper condition is present; and

(f) transmitting a signal indicative of a tamper condition whenever the amplitude of said optical signal reflections is greater than said optical sensor baseline.

47. The method of claim **44** further comprising the steps of:

(a) alternately activating said three sensors at a third predetermined interval whenever said third set of signals disappear to determine if a parked vehicle has departed;

(b) monitoring the change in amplitude of any reflected signals from said alternate activation of said three sensors at said third predetermined interval that correspond to a predetermined range away from said three signal-emitting sensors; and

(c) transmitting a signal indicative of a tamper condition whenever said change in amplitude is greater than a second predetermined threshold or less than a third predetermined threshold.

48. The method of claim **41** wherein said step of positioning a third signal-emitting sensor between said two signal-emitting sensors comprises orienting said two signal-emitting sensors in opposite directions at an angle in the range of 0 to 45 degrees from a vertical plane.

49. The method of claim **41** wherein said step of positioning a third signal-emitting sensor between said two signal-emitting sensors comprises orienting said two signal-emitting sensors in opposite directions at an angle of 22½ degrees from a vertical plane.

50. The method of claim **28** wherein said first predetermined interval comprises one second.

51. The method of claim **28** wherein said second predetermined interval comprises 50 msec.

52. The method of claim **28** wherein said predetermined threshold is the noise level of the parking space.

53. The method of claim **28** wherein the predetermined number of consecutive reflected signals is six.

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